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CONTEXT EFFECTS IN MOVEMENT JUDGMENT

by

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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Context Effects in Movement Judgment," submitted by Graham J. Fishburne in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Human Performance.

Date ..17th June, 1980........

DEDICATION

This thesis is dedicated to the special people in my life. To my parents who have given so much throughout their life and have asked for so little in return. This thesis offers an opportunity to return a small portion of their unselfish devotion.

To Dianne, who has been so patient and encouraging throughout the realization of this thesis, I will always thank.

Finally, I dedicate this thesis to the rest of my family and friends who have always encouraged me to pursue my interests and goals in life.

ABSTRACT

A series of seven experiments were conducted to investigate the effects of context on the recall and recognition of movement distance. Movements were made with a cursor attached to a linear slide, and vision was eliminated. The effect of anchor movements on criterion movement recognition was to cause directional biasing in recognition judgment. The direction of the biasing was toward the magnitude of the anchor stimulus. Interpretation of the directional biasing effects on recognition judgment are discussed in terms of retroactive assimilation theory (Helson, 1964). The indication is that the anchor movement interferes with the memorial representation of the criterion movement, and hence causes a directional bias in recognition judgment.

The effect of anchor movements on reproduction accuracy of a criterion movement were dependent upon both the size of the anchor movement and the size of the criterion movement. Reproduction accuracy of the small criterion movements were not significantly biased by anchor movements. Reproduction accuracy of long movements were significantly biased by the inclusion of anchor movements. The resistance of short movements to directional biasing is discussed in terms of the theory of differential encoding according to movement length (Laabs, 1977, 1980).

The direction of the bias in reproduction accuracy was dependent upon the length of the anchor movement. Anchors longer and shorter than the criterion movement caused directional biasing toward the magnitude of the anchor movement. Extremely long and extremely short anchor movements caused directional biasing effects in a direction away from the magnitude of the anchor movement. The differential biasing effects associated with the relative length of the anchor stimulus, are discussed in terms of retroactive assimilation theory (Helson, 1964) and proactive contrast theory (Ellis, 1971, 1973a). The indication is that anchors in general cause interference effects with the memorial representation of the criterion movement (assimilation). However, extremely long and extremely short anchor movements cause a perceptual illusion and consequently affect the reception of a subsequent stimulus (contrast).

Recognition judgments were found to be unbiased when an empty time interval was included between a standard and comparison movement. Recognition judgments of movement length do not appear to be subject to the normal time-error effects frequently associated with perceptual judgments.

The effectiveness of a recognition paradigm known by the acronym KAK, to detect directional biasing effects in a movement context situation, was assessed. The KAK recognition paradigm proved effective in detecting directional biasing due to anchor stimuli.

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Although the history of motor memory can be traced back to about the turn of the century (Woodworth, 1899), research in the area did not really establish itself until the late 1960's. The reason for the late arrival of such an important area of research is bound up in the historical development of psychophysics and the gradual emergence of an accepted psychological framework for human memory.

The typical experimental paradigm for the examination of motor short-term memory (MSTM) is the presentation of a criterion item(s), a retention interval which may or may not involve a distractor task, and then recall of the criterion item(s). This paradigm was initially utilized by Brown (1958) and Peterson and Peterson (1959) in experimental psychology. Adams and Dijikstra (1966) were the first MSTM researchers to employ this procedure. Following their lead, numerous researchers investigated retention and interference effects in MSTM (Ascoli & Schmidt, 1969; Posner, 1967; Stelmach, 1969), and more recently, the encoding and retention characteristics of movement attributes (Diewert, 1975; Gundry, 1975; Laabs, 1973; Marteniuk, 1973; Roy, 1977). Over the past 20 years movement reproduction has predominated as the memory task in studies involving the short term retention

of movement information.

The experimental paradigm outlined above is basically the "method of adjustment", which finds its roots in psychophysics. MSTM researchers have followed the lead of classical psychophysics, and have turned to established psychophysical theories to explain movement retention findings. One such example is the area of context effects.

Context effects refer to the influence of relevant past or present stimulation upon the on-going judgment made by an organism (Philip, 1949). Context effects in perceptual judgment have been studied for over a century, and, as a result, several well established theories have been reported to account for their effects (Helson, 1964; Lauenstein, 1932; Parducci, 1965). Recently, MSTM researchers became interested in context effects, when they considered reproduction accuracy of a motor movement to be influenced by the context in which it appeared (Laabs, 1973; Pepper & Herman, 1970; Stelmach & Walsh, 1973).* The context has been varied in MSTM studies by the inclusion of extra stimuli along the same dimension as the to-be-recalled criterion movement. Stimuli which constitute the context are often referred to as *anchors*. Anchors then, are stimuli which induce systematic distortions in the judgment of other stimuli.

* See Appendix A for a full review of context effects in perceptual judgment, theories of context effects, and MSTM theories related to context effects.

The effective action of anchors is limited to either of two processes: they may attract (assimilation) or repel (contrast), other judgmental stimuli. This is demonstrated in perceptual judgment studies where a shift in constant error (CE) occurs as the result of anchors presented either prior to, or interpolated between, a standard stimulus and its comparison judgment. The CE changes are generally in the direction of the magnitude of the anchor stimuli (assimilation). Assimilation effect is the most common finding in perceptual judgment studies.* Movement reproduction studies show similar assimilation effects. When anchors are presented either before or after a criterion motor movement, the general finding on reproduction of the criterion is a shift in CE toward the level of anchor stimulation (Craft, 1973; Craft & Hindrichs, 1971; Herman & Bailey, 1970; Laabs, 1974; Patrick, 1971; Pepper & Herman, 1970; Stelmach & Kelso, 1975; Stelmach & Walsh, 1972, 1973).

Both perceptual judgment and MSTM studies report assimilation effects, yet the expected shift in CE has not been observed in all conditions tested. A number of perceptual judgment studies report contrast effects as

* In perceptual judgment studies using rating scales, changes in category are usually in the direction away from the level of anchor stimulation and are termed contrast; but the point of subjective equality shifts in the direction of the anchor stimulation producing a true assimilation effect.

opposed to assimilation (Christman, 1954; Ellis, 1971, 1972, 1973a; Pratt, 1933; Sherif, Taub, and Hovland, 1958; Turchioe, 1948). A contrast effect is exhibited when the point of subjective equality is moved in a direction away from the level of anchor stimulation. For example, Christman (1954) found that judgments of auditory pitch did not shift in the direction of a preceding higher or lower tone of long duration, but instead shifted in the opposite direction (contrast effect).

There are perceptual judgment studies which report both contrast and assimilation effects taking place (Sherif, Taub, and Hovland, 1958; Turchioe, 1948). Turchioe studied the ability of subjects to estimate temporal intervals when anchor stimuli were presented either before or after a standard stimulus. She found assimilation effects when the anchor followed the standard, and contrast effects when the anchor preceded the standard.

Sherif, Taub, and Hovland (1958) suggest the relative size of the anchor stimulus determines whether assimilation or contrast takes place. Using lifted weight as stimuli, Sherif et al found two anchor ranges in existence; a range immediately above or below the stimulus series in which assimilation occurs, and another range beyond this where contrast occurs.

It appears from the results of the Sherif et al study that anchors immediately above or below the standard stimulus cause the expected move in point of subjective

equality toward the anchor level. However, with very large or very small anchors the effect is to cause a contrast with the standard, thus moving the point of subjective equality in a direction away from the anchor level. Where the exact cross-over occurs is not clear, but presumably depends on the particular stimuli being judged.

Only two MSTM studies report contrast effects similar to those cited in perceptual judgment studies. Levin, Norman, and Dolezal (1973) report on the reproduction of average movements. Longer movements of a pair to be averaged were given more weight in the averaging process, especially when the judgments were preceded by a series of reproductions of much smaller movement. These results may be considered as a contrast effect.

The only clear case of contrast in movement reproduction was found by Laabs (1971) in an experiment requiring concurrent information processing during the recall of end location. Changes in concurrent task information caused a positive shift in CE which Laabs interpreted as a contrast effect.

MSTM researchers have relied on the theories of assimilation and adaptation level (Helson, 1964) to account for a shift in reproduction CE toward the level of anchor stimulation. Although this is the usual case, there are a number of studies reported where researchers have failed to find assimilation effects under all anchor conditions

(Kerr, 1978; Laabs, 1971; Levin, Norman, and Dolezal, 1973; Patrick, 1971; Stelmach & Kelso, 1973; Stelmach & Walsh, 1972, 1973). The operation of a perceptual contrast effect (illusion) may have contributed to these failures.

Whether anchor stimuli cause assimilation or contrast effects is extremely important in terms of MSTM. If the anchor operates retroactively, it can be assumed to affect the memory trace of the preceding stimulus (assimilation), but if the anchor operates proactively, due to perceptual contrast effects, it will have an effect on the reception of the subsequent stimulus.

The assimilation effect is the most prevalent finding in MSTM context studies. A number of researchers however, report conditions which did not produce the expected directional biasing associated with assimilation effects. For instance, anchors smaller than the criterion were found to be ineffective in certain studies (Patrick, 1971; Stelmach & Walsh, 1972, 1973). Anchors were also found to be ineffective when presented in a direction opposite to the criterion stimulus (Herman & Bailey, 1970; Stelmach & Barber, 1970). Finally, the MSTM studies of Laabs (1971) and Levin et al (1973) exhibited contrast effects.

Sherif et al (1958) suggest the relative size of anchor stimulus may be the determining factor in producing either contrast or assimilation effects in perceptual judgment. No MSTM research has systematically examined

the effects of either extremely longer or extremely smaller anchor stimuli. Further, psychophysical experiments in perceptual judgment have revealed both negative and positive time-errors which are dependent upon the particular stimuli being tested, and, more importantly, upon the interstimulus interval. MSTM studies have neglected time-error effects. No study has specifically investigated time-error effects in MSTM.

On reflection, the MSTM studies which failed to reveal directional biasing under certain anchor conditions, may have done so for one or more of the following reasons:

1. Perceptual contrast effects working in opposition to assimilation effects.

2. A negative or positive time-error in operation, confounding anchor effects.

3. There is total ineffectiveness over a certain range of anchor stimuli.

4. The experimental paradigm employed and/or dependent variable used in the MSTM study was insensitive to weak anchor effects.

The four possible reasons outlined above to account for variation in anchor conditions, have not been systematically studied in MSTM research.

The standard reproduction accuracy task (recall paradigm) has been employed in nearly all MSTM studies involving context effects. Recognition paradigms apparently have rarely been employed. Also, a variety of different interstimulus

intervals have been used without consideration of time-error effects. Perceptual contrast has been reported but no reasons postulated as to why it occurs or when it occurs; and finally, no MSTM study has considered the range of effectiveness of the anchor stimulus.

The following series of experiments were carried out to investigate the effects of context on the recall and recognition of motor movement distance. More specifically, the studies were conducted to:

1. Assess the role of perceptual contrast and assimilation in directional biasing as a result of the presence of anchor stimuli.

2. Determine the effect of time-error in the successive comparison of two objectively equal motor movements.

3. Assess the range of effectiveness of an anchor stimulus as a directional biasing agent when its relative magnitude is varied.

4. Assess the effectiveness of a recognition paradigm in detecting directional biasing as a result of anchor stimuli.

The criterion and reproduction movements used in the following experiments were subject produced, self-paced slow movements. The use of slow self-paced movements was to reduce any effects of changing speeds on movement reproduction (Woodworth, 1899). The movements were subject defined since there is evidence indicating

performance is altered on a MSTM task when criterion movements are passively presented rather than actively generated by the subject. Active movement not only results in better immediate reproduction but is also retained better than passively induced movement (Jones, 1974; Marteniuk, 1973).

The recognition paradigm utilized in the following set of experiments was first presented by Underwood (1966) and later developed by Ellis (1971). It will be known by the acronym KAK which represents two constant stimuli (K) with an interpolated anchor (A).*

* See Appendix B for a review of recognition versus recall paradigms in MSTM, plus a full description of the KAK recognition paradigm.

EXPERIMENT I

The Effect of Anchor Stimuli on Movement Recognition

The principles of adaptation-level theory may be applied to comparative judgments involving interpolated anchors. Helson (1964) has made the implicit assumption that such anchors pool with the standard as well as previous stimuli to form an adaptation level against which the comparison stimulus is judged. That is, he envisages a process of *retroactive assimilation*.

The research of Guilford and Park (1931), Needham (1933a), Philip (1947), and Pratt (1933) support the retroactive assimilation model. Interpolated anchors greater than the standard and comparison stimuli produce a tendency to underestimate the latter, while lesser anchors lead to its overestimation. In Helson's (1964) view the adaptation level would be, for these two situations, respectively, high and low.

These results, though, could just as well be accounted for by a model involving the process of *proactive contrast* between the anchor and the comparison stimulus. This model, proposed by Ellis (1971), ignores any changes in the memory of the standard stimulus, and instead proposes that greater anchors act to depress the sensation of the subsequent comparison stimulus. Lesser anchors, on the other hand, lead to an enhancement of the apparent intensity of the comparison stimulus.

To test this alternative model, Ellis (1971, 1973a)

used comparative judgments involving two objectively equally loud stimuli, in a KAK recognition paradigm. The KAK paradigm involved the comparison of a standard stimulus (K1) with itself (K2) while an anchor stimulus was interpolated between them. The subjects failed to realize that K1 and K2 were equal since the presence of the interpolated anchor produced the illusion K2 was greater than K1, or K2 was less than K1, depending on whether the anchor was lesser or greater than the standard.

So far the two models, retroactive assimilation, Helson (1964), and proactive contrast, Ellis (1971, 1973a), are equally plausible, since both predict the same results when anchors are interpolated between K1 and K2. However, when the anchor appears before K1 (precedes) or follows K2, the predicted outcomes are quite different. According to retroactive assimilation, placing the anchor before K1 should not markedly alter the effect produced when it is interpolated between K1 and K2, since in both cases K1 and the anchor will pool to form the adaptation-level against which K2 is judged. On the basis of proactive contrast though, the two designs should result in opposite outcomes. In the preceding condition the anchor will operate proactively on K1, and in the interpolated condition the anchor will operate proactively on K2. When the anchor follows K2, there should be no discernible effect according to the proactive contrast theory, but on the basis of retroactive assimilation, the anchor, in pooling with K2,

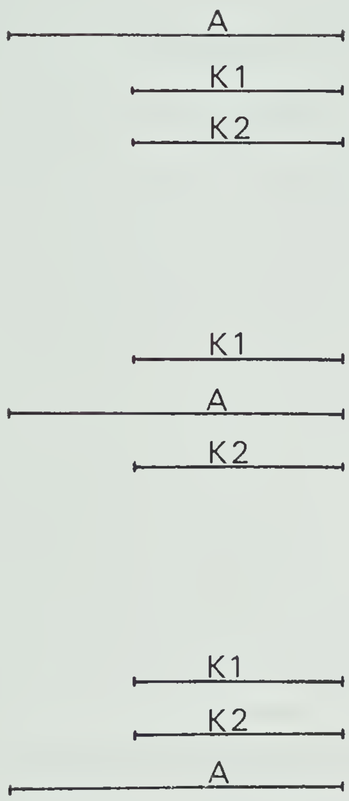
should produce the opposite effect to when it is interpolated.*

The K2 vs. K1 judgmental outcomes on the basis of retroactive assimilation (Helson, 1964) and proactive contrast (Ellis, 1971, 1973a), for the three possible anchor positions in a KAK paradigm, is illustrated in Figure 1.

When anchors preceded or followed the standard in Ellis' studies, he concluded proactive contrast was in effect rather than retroactive assimilation. That is, the anchors operated proactively to form perceptual contrast effects which thus affected the reception of subsequent stimuli.

MSTM researchers have recently put forward three theories to account for the directional biasing associated with anchors presented either before or following a standard movement. Pepper and Herman (1970) suggested directional biasing is a result of an interaction between the anchor and standard memorial traces. Recall response is based upon the weighted combination of both anchor and standard traces. A model by Laabs (1973) assumes directional biasing is the result of a subject reproducing a movement both in reference to the memory trace of the movement and in reference to the adaptation-level of the

* The condition where the anchor follows K2 is difficult to interpret in terms of adaptation-level theory.



ANCHOR POSITION	RETROACTIVE ASSIMILATION	PROACTIVE CONTRAST
Preceding $\boxed{P}$	K2 < K1	K2 > K1
Interpolated $\boxed{I}$	K2 < K1	K2 < K1
Following $\boxed{F}$	K2 > K1	K2 = K1

Figure 1. K2 vs. K1 outcomes on the basis of Retroactive Assimilation (Helson, 1964) and Proactive Contrast (Ellis, 1971, 1973a) for the three possible anchor positions.

set of movements presented. Finally, Stelmach and Walsh (1973) explain directional biasing in terms of both decay and interference theory. The criterion memory trace is assumed to decay over time and so becomes more and more susceptible to interference from the memory trace of an anchor stimulus presented sometime after the criterion. The later an anchor is presented after presentation of the criterion, the more susceptible is the criterion trace to interference from the anchor trace.

All three MSTM theories evoke the principles of retroactive assimilation (Helson, 1964) to explain directional biasing. That is, they infer that anchors operate retroactively and thus affect the memory trace of the preceding stimulus.

The following experiment was established to test if retroactive assimilation operates in all conditions for which anchor stimuli are presented. That is, for anchor stimuli presented before, between, and/or following a standard and comparison stimulus.

MSTM theories associated with context effects are based upon the results of motor movement retention studies, examined through reproduction (recall) paradigms. The possible effects of anchor stimuli upon movement retention utilizing recognition paradigms have not been adequately considered in MSTM studies. To this end, a recognition paradigm was employed in this first experiment to study context effects as they affect motor memory.

In addition to the main aim of the experiment, two secondary aims were investigated. One was to discover if response order effects occur in the KAK situation. That is, judging whether the second movement (K2) relative to the first (K1) produces different results than judgments of K1 relative to K2. Such a difference might be expected from the comparative judgment literature wherein standard versus comparison judgments have sometimes been reported to differ from comparison versus standard judgments (Michels & Helson, 1954).

The final aim of this first experiment was to determine if there is a time-error associated with the retention of motor movement information.

Method

Subjects

Four male and four female subjects (aged 19-29 years) participated in this experiment. The eight subjects were undergraduate students who wrote with their right hand.

Apparatus and Task

A calibrated meter bar mounted on a laboratory table top served as the track on which linear movement distances were produced by the subjects. The subject made these distances by moving a metal cursor with a metal handle. A schematic representation of the apparatus is illustrated in Figure 2.

A PDP 11 digital computer was used to control the experiment. The computer was programmed to control stimulus durations and interstimulus intervals via a E.I.C.O. Audio Wave Tone Generator (0-200 KHz). The duration of events within each trial is illustrated in Figure 3. The tone was generated by the computer activating a solid state switch (via a digital to analog converter). This switch operated the E.I.C.O. generator to produce the tone, which, in turn, served both to cue the subject by heralding each new trial and to standardize the hand slide movements. The interaction between apparatus and computer is shown in Figure 4.

The subject was seated in front of the apparatus and held the metal cursor handle with his right hand. Hand

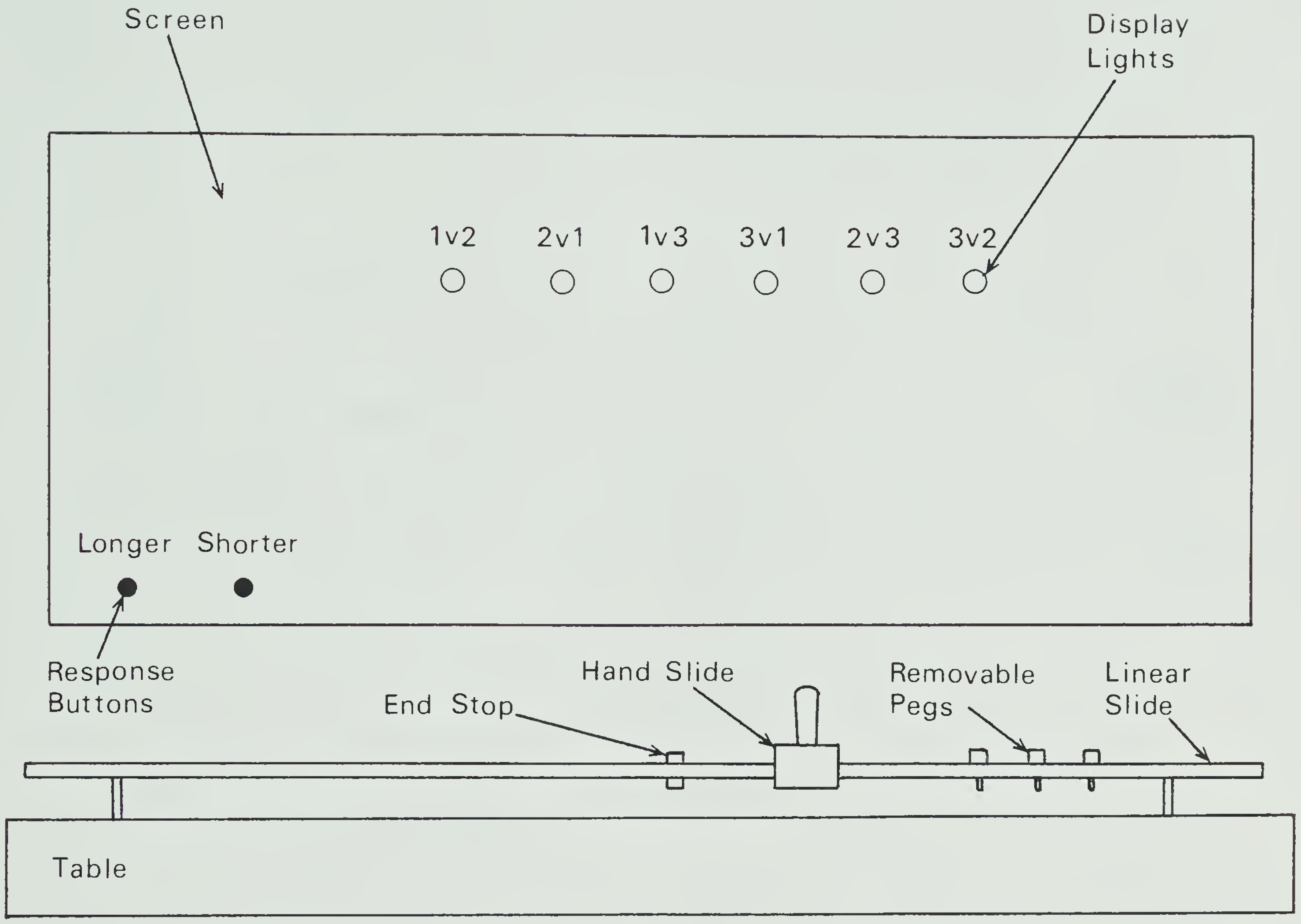


Figure 2. Schematic representation of apparatus.

Figure 3. The order and duration (in seconds) of events in each trial.

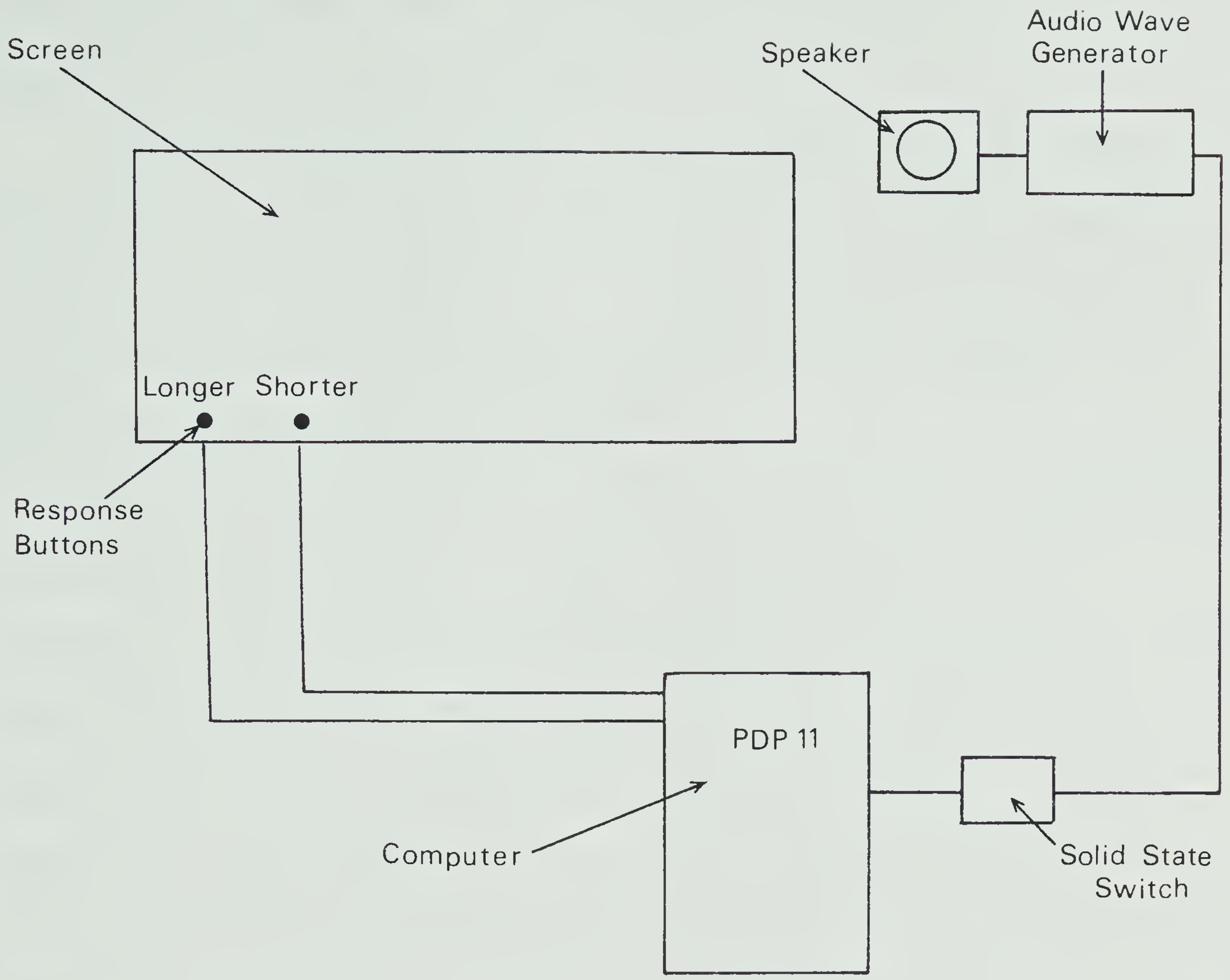


Figure 4. Interaction between apparatus and computer.

slide movements from the start position were only allowed in one direction, i.e. a right to left direction. A screen was mounted over the subject's right arm. The movement of the arm was blind.

Attached to this screen, and in front of the subject, was a panel containing six display lights. These lights served to cue the subject as to which two of the three movements presented on each trial he was to compare. Comparisons were made on length.

The task required the subject to be seated approximately 30 cm away from the hand slide. A warning tone of 2 seconds duration instructed the subject to take hold of the hand slide with his right hand. A second tone of short duration (0.5 seconds) was the signal to commence movement along the slide (right to left) to a predetermined physical stop. The predetermined start positions were organized by the adjustment of a peg to one of three set positions: 10 cm, 15 cm, or 20 cm from the stop position (the end location remained constant with the start position being varied). A third tone, also of short duration, was the signal to release the hand from the hand slide. This cycle was repeated three times and constituted one trial. Having received three linear movements a panel display light indicated which two of the three movements to compare in terms of length. The six display lights were numerically assigned to the six comparison combinations (i.e. 3 vs. 1, 3 vs. 2, 2 vs. 1, 2 vs. 3, 1 vs. 3, 1 vs. 2). The first

number indicated which movement to compare ('longer' or 'shorter') to the second numbered movement. For example, 3 vs. 1 required the subject to decide if movement three was 'longer' or 'shorter' than movement number one. The subject recorded his decision by depressing one of two buttons indicating 'Longer' or 'Shorter'. The subject's decision was recorded by the PDP 11 computer and stored. The subject's decision was forced choice in that no equal judgments were allowed.

Design

The experiment consisted of a 3-way factorial repeated measures design. The number of levels of the three factors were: 2 (order of judgment) X 3 (anchor size) X 3 (anchor position). Each subject received 5 trials for each of the randomly presented conditions.

Procedure

When the subject was comfortably seated in front of the apparatus he was given the following instructions:

> "The following experiment is an investigation of how people make relative judgments of movements when the differences between stimuli are small. Each trial is preceded by a tone of long duration. This will be your signal to take hold of the metal cursor handle with your right hand. A second tone of short durartion will be your cue to commence

movement of the cursor (right to left) to its end stop. Your hand will remain holding the cursor until a third tone, also of short duration, is heard, whereupon you release the cursor. This cycle will be repeated until you have received three movements from which you must compare two. You will however, be unaware as to which two to compare until you have received all three movements. The third movement will be followed by the illumination of a display light. This will indicate, for example, 2 vs. 1, which means that you must recall the <u>second</u> movement and compare it with the <u>first</u> movement. You must respond either 'Longer' or 'Shorter' as promptly as possible by depressing the appropriate button. No equal judgments are allowed so if you really cannot decide, then guess."

The standard stimulus (K1) and comparison stimulus (K2) were each set at 15 cm. The three anchor lengths used were 10 cm, 15 cm, and 20 cm, thus providing anchors of less than, equal to, and greater than the standard and comparison stimuli.

Fifty practice trials were then given in order to familiarize the subjects with the rather complex procedure. Thirty of these trials involved real differences so the experimenter could note if subjects had failed to

grasp the procedure. In fact, no subject required remedial training. After the practice trials subjects were allowed a 5 min. break before proceeding with the first session. The second session (held on a subsequent day) was preceded by 15 practice trials, 10 of which involved real differences. Each session consisted of 57 trials. Table 1 summarizes the distribution of the 114 trials for the five conditions experienced by each subject, i.e., anchors preceding (P), interpolated (I), and following (F) the comparison stimuli, as well as two no-anchor conditions.

The three anchors used were 10 cm, 15 cm, and 20 cm lengths, and each of these occurred a total of 30 times (15 each session). The three anchor positions were each used a total of 10 times, and the six possible number combinations (i.e. 3 vs. 1, 3 vs. 2, 2 vs. 1, 2 vs. 3, 1 vs. 3, and 1 vs. 2) each occurred a total of 15 times. These were all separately randomized. Randomization was attained through random number generation on the PDP 11 computer.

There were 24 further trials in which only K1 and K2 were presented; half of these involved an interstimulus interval of 2 seconds and the remainder, an interstimulus interval of 6 seconds.

Data Analysis

In order to make the K1 vs. K2 judgments compatible with the K2 vs. K1 judgments, they were converted to

Table 1

Distribution of Trials Among the
Five Conditions

No. of Trials	Condition	Comparisons
30	Preceding (P) = AKK	3 vs. 2; 2 vs. 3
30	Interpolated (I)= KAK	3 vs. 1; 1 vs. 3
30	Following (F) = KKA	2 vs. 1; 1 vs. 2
12	KK (2 second interval)	2 vs. 1; 1 vs. 2
12	KK (6 second interval)	2 vs. 1; 1 vs. 2

NOTE: K = Standard and comparison stimuli

A = Anchor stimulus

proportions and this value subtracted from unity. Thus 0.1 judgments K1<K2 are equivalent to a proportion of 0.9 K2<K1 judgments.

The proportion of judgments K2<K1 for all conditions, each anchor, and both orders of judgment are given in Table 2 and illustrated in Figure 5.

Results

The data were submitted to a repeated measures analysis of variance. The analysis failed to reveal any significant main effects or interactions.

The mean anchor data were submitted to proportion '*t*' tests to compare the anchor effects with the chance proportion of 0.5 (which would be expected if the anchor had no effect). No significant differences were in evidence for any anchor condition.

Results of trials without an anchor stimulus are as follows:

The proportion of judgments K2<K1 for each interstimulus interval and both orders of judgment are shown in Table 3.

The data were submitted to a repeated measures analysis of variance. The analysis failed to reveal any significant main effects or interactions. There was no appreciable order effect (i.e. K1 vs. K2, or K2 vs. K1) and so the results were pooled. The mean K2 vs. K1 proportions were 0.52 and 0.46 for the interstimulus intervals of 2 and 6 seconds respectively, which is quite close to chance

Table 2

The Proportion of Judgments K2‹K1 for
Each Subject Under Each Condition

Condition	Subject	ORDER OF JUDGMENT					
		K2 vs. K1			K1 vs. K2		
		ANCHOR SIZE (cm).			ANCHOR SIZE (cm).		
		10	15	20	10	15	20
Preceeding	1	.40	.40	.20	.20	.40	.20
	2	.40	.60	1.00	.60	.60	.60
	3	.40	.00	.00	.20	.00	.20
	4	.20	.40	.00	.20	.00	.00
	5	.20	.40	.40	.20	.20	.40
	6	.40	.40	.80	.60	.40	.40
	7	.80	.40	.40	.40	.40	.80
	8	.20	.40	.20	.20	.40	.00
	$\bar{x}$	.38	.38	.38	.33	.40	.33
Interpolated	1	.20	.40	.20	.40	.40	.00
	2	.80	.40	.60	.40	.60	1.00
	3	.00	.20	.20	.20	.20	.60
	4	.60	.00	.20	.20	.00	.20
	5	.20	.60	.40	.20	.40	.40
	6	.00	.80	.80	.20	.80	.60
	7	.60	.60	.40	.80	.40	.80
	8	.60	.60	.40	.20	.60	.40
	$\bar{x}$	.38	.45	.40	.33	.43	.50
Following	1	.60	.20	.40	.20	.40	.40
	2	.60	.60	.40	.80	.60	.60
	3	.40	.40	.60	.60	.40	.20
	4	.20	.00	.00	.40	.00	.20
	5	.60	.40	.80	.40	.60	.40
	6	.40	.20	.00	.60	.00	.40
	7	1.00	.80	.60	.80	1.00	.60
	8	.40	.60	.00	.20	.40	.20
	$\bar{x}$	.53	.40	.35	.50	.43	.38

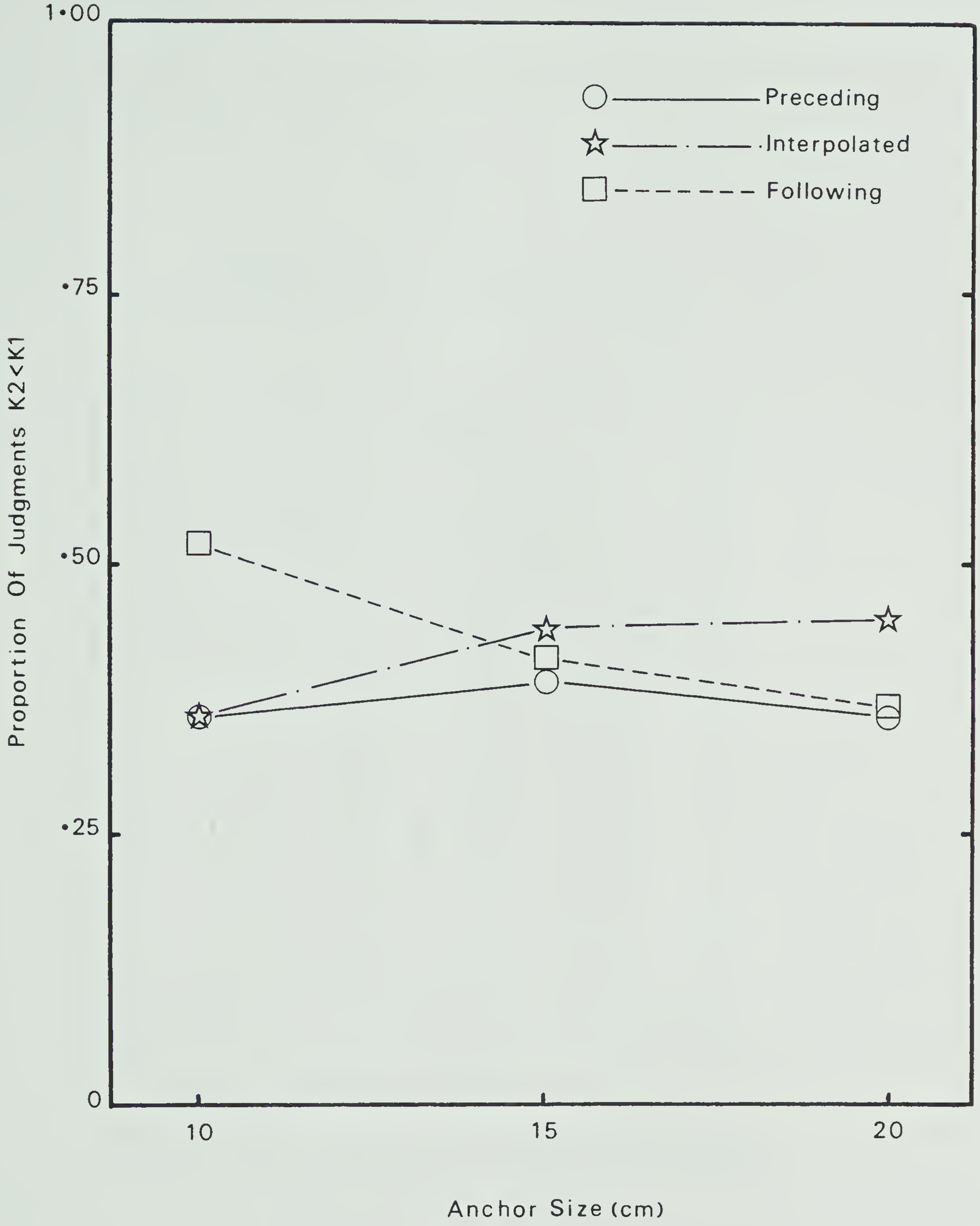


Figure 5. The proportion of judgments K2<K1 at each anchor level (collapsed across order condition) for the three anchor positions: P (preceding), I (interpolated), and F (following).

Table 3

The Proportion of Judgments K2<K1
for Trials Without an Anchor Stimulus

S	ORDER			
	K2 vs. K1		K1 vs. K2	
	ISI (sec)		ISI (sec)	
	6	2	6	2
1	0.67	1.00	0.17	0.33
2	0.67	0.33	0.67	0.67
3	0.17	0.67	0.00	0.50
4	0.50	0.50	0.50	0.50
5	0.83	1.00	0.17	0.00
6	0.67	0.17	0.33	0.50
7	1.00	0.67	0.00	0.17
8	0.83	0.50	0.17	0.67
$\bar{x}$	0.67	0.61	0.25	0.42

NOTE: K1=K2= Standard and Comparison Stimuli
ISI = Interstimulus Interval
S = Subject

proportion (0.5). Proportion '_t_' tests revealed that the means for both 2 second and 6 second interstimulus intervals did not significantly differ from chance.

Discussion

The anchor stimuli failed to produce any significant context effects. Neither proactive contrast effects nor retroactive assimilation was in evidence.

A number of studies (Keele and Ells, 1972; Laabs, 1973; Marteniuk and Roy, 1972; and Marteniuk, 1973) have been concerned with isolating different cues upon which movement reproduction is based. Two main sources of information available to subjects when they attempt to reproduce a standard movement in the absence of visual feedback, are distance and location cues. Subjects can move for a certain distance or move to a certain location. Using distance information subjects can reproduce the amplitude of the standard movement, and using location information they can reproduce the terminal point of the standard movement. The evidence concerning distance and location cues is not clear and is often contradictory. There is evidence to suggest that subjects spontaneously use distance for short movements and location for long movements (Gundry, 1975). However, where the cross-over takes place, or what constitutes a long or short movement is not made clear. Tannis (1977) found end location to be the strongest cue for recall of movement information. In the present study end location was made consistent, and this may have severely diminished the directional biasing effects reported in other studies.

Directional biasing may have been further diminished

due to the relative size of the anchors used in this study. It is quite possible the comparative length of the anchors used in the study were not sufficiently different from the standard stimulus to cause a noticable assimilation effect. Helson (1964) notes that there is a critical value or region where stimuli become too weak to change the adaptation level, however, this critical value depends on the type of psychophysical judgment being tested. If the relative size of the anchors were not sufficient to cause retroactive assimilation or proactive contrast effects then the subject will have been forced into guessing his response. The decision made by the subject was forced choice (i.e. 'longer' or 'shorter'), which made no allowance for the judgments 'same' or 'do not know'. Had the subject been given the opportunity, he may have frequently depressed 'same' or 'do not know' buttons.

The finding that it makes no difference whether judgments are made K1 relative to K2, or K2 to K1 contradicts the so called order effect previously reported. Different adaptation level formulations have been put forward to take into account the order of judgment (Michels and Helson, 1954), however, the present data suggests that postcuing as to which stimulus to consider as the standard erradicates the order effect.

The trials in which only K1 and K2 appeared resulted in nonsignificant differences in judgment between interstimulus intervals of 2 and 6 seconds, and chance

proportions. From this it may be concluded that a time-error was not in evidence for both interstimulus intervals tested. It appears that movement information is not subject to the effects of time-error in the same way many other perceptual stimuli are shown to be (Needham, 1934).

The trials in which only K1 and K2 appeared also resulted in a non-significant difference in judgment between an interstimulus interval of 2 seconds and one of 6 seconds. This finding is at variance with many perceptual judgment studies (Ellis, 1971, 1972, 1973a, 1973b; Philip, 1947; Needham, 1934, 1935b) regarding the effects on time-error as the interstimulus interval is varied. Also, a reversal in the direction of time-error as a function of the interstimulus interval, has frequently been reported in perceptual judgment studies (Ellis, 1971, 1972; Kohler, 1923; Pratt, 1933; Underwood, 1966). Interstimulus intervals of less than 3 seconds commonly lead to positive time-error, whereas thereafter, negative time-error prevails. Movement information does not appear to be subject to changes in time-error when interstimulus intervals operate through this perceptual judgment time-error reversal zone.

EXPERIMENT 2

Encoding and Retention Characteristics of Movement Information Cues

Recently MSTM researchers have been concerned with the attributes of a movement. There is a wide array of information inherent in a movement that may be used as a cue for later recall, such as distance, end-location, force, direction, acceleration, deceleration, velocity, etc. Two of the more prominant cues available for the recall of a movement are its distance and end location (Laabs, 1979). Diewert (1975), Laabs (1971, 1973), and Marteniuk (1973, 1975) considered the encoding and retention characteristics of distance and location cues, using a unidimensional task. Diewert (1975) and Marteniuk (1975) suggested that location and distance information were differentially encoded in memory with distance being encoded less precisely. Laabs (1973) reports that distance and location also have different retention characteristics. He contends that distance information spontaneously decays over time while location information is rehearsable and subject to interference from interpolated activity.

Since Laabs (1973) has shown that location information is rehearsable and has different retention characteristics than distance, it could be suggested that the subjects in Experiment 1, were concerned more with the acquisition of location points during the movement lengths than with the acquisition of movement between the locations.

The stability of end-location in Experiment 1 may

have produced a valuable cue for accurate recall and recognition of the movement stimuli. Tannis (1977) found end-location to be the strongest cue for recall of movement information. Laabs (1975, 1978) studied the effects of location and distance cues on the recognition of movement information. He concluded that recognition when using the location cue was much better than when using distance cue.

Separation of distance and location cues is accomplished by using different starting points for the movement stimuli, which makes one or the other cue unreliable at recall or recognition (Laabs, 1979).

One of the reasons postulated for the lack of directional biasing found in Experiment 1 was the possibility of a subject using end point location as a valuable memory cue. Only start location was made unreliable, thus allowing the stable location end point to be used as a memorial cue (Laabs, 1973, 1975; Tannis, 1977). The following experiment was established to consider the effect location cue has upon the directional biasing associated with anchor stimuli. Three main conditions of movement were tested:

1. End location reliable, start location unreliable. (A replication of the condition tested in Experiment 1.)
2. Start location reliable, end location unreliable.
3. Start location unreliable, end location unreliable.

Method

Subjects

Five male and four female subjects (aged 19-24 years) who had never participated in a psychological experiment before, participated in this experiment. The nine subjects were undergraduate students who wrote with their right hand.

Apparatus and Task

The apparatus was identical to that described in Experiment 1.

The task was identical to that described in Experiment 1 with two minor modifications. Within each trial one of three conditions prevailed:

1. The end location was fixed and the start location varied.
2. The start location was fixed and the end location varied.
3. Both start and end locations were varied.

A trial consisted of three linear arm movements, two of which had to be compared for length upon termination of the trial.

The three location point conditions are represented schematically in Figure 6. The third condition (3) deserves a note of qualification. The adjustment pegs were arranged so the subject *physically* received the anchor stimulus on the linear slide, inbetween the standard

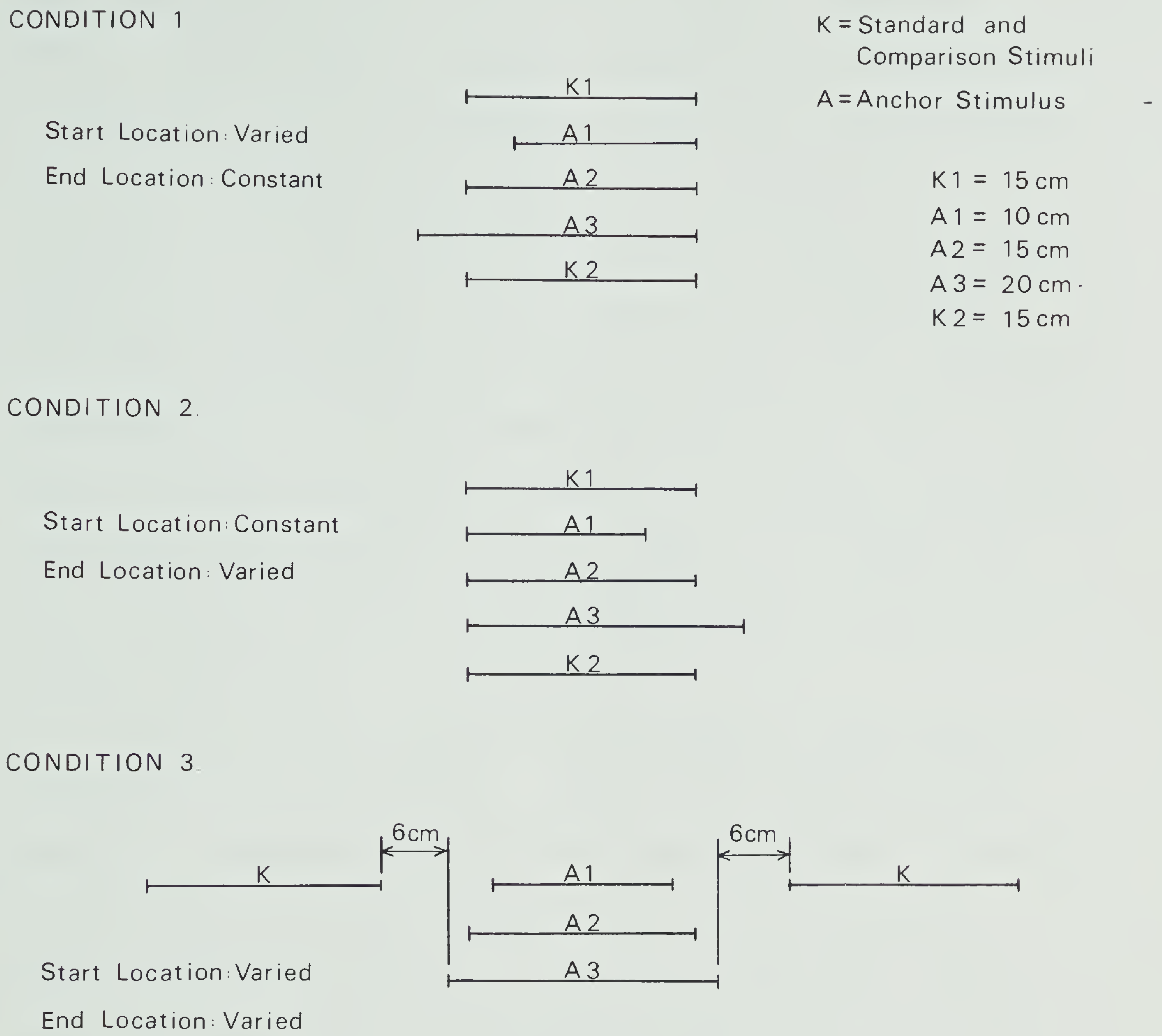


Figure 6. Start location and end location conditions.

and comparison stimuli. However, within a trial the subject experienced the anchor movement in a preceding (P), interpolated (I), or following (F) position. The standard (K1) and comparison (K2) stimuli were represented physically on either side of the anchor. Computer randomization for each trial within condition (3) determined which side represented the standard stimulus (K1) and which side represented the comparison stimulus (K2). The physical separation between anchor and standard, and anchor and comparison stimuli was 6 cm. That is 1 cm more than the difference between the stimulus movement lengths used in this experiment.

The second modification was a change in the duration of events within each trial. Due to more complex slide movements within condition (3) it was necessary to increase the ISI from 6 seconds (Experiment 1) to 9 seconds to permit efficient movement of pegs and hand slide. The order of events remained the same as Experiment 1, only the duration was changed. The duration of events within each trial for Experiment 2 is illustrated in Figure 7.

Design

The experiment consisted of a 4-way repeated measures factorial design. The four factors were made up of the following levels: 3 (start and end location condition) X 2 (order of judgment) X 3 (anchor size) X 3 (anchor position).

Figure 7. The order and duration (in seconds) of events in each trial.

Each subject received 5 trials for each of the randomly presented conditions.

Procedure

When the subject was comfortably seated in front of the apparatus he was read the same procedural instructions reported in Experiment 1.

The standard and comparison stimuli (K1 and K2) were set at 15 cm. The three anchor lengths used were 10 cm, 15 cm, and 20 cm, thus providing anchors of less than, equal to, and greater than the standard stimulus.

Fifty practice trials were given in order to familiarize the subjects with the rather complex procedure. Thirty of these trials involved real differences so the experimenter could note if the subject had failed to grasp the procedure. In fact, no subject required remedial training. After the practice trials subjects were allowed a five minute break before proceeding with the first session. The first session consisted of only 20 trials due to the larger number of practice trials experienced by the subject. Five further sessions (each held on subsequent days) were preceded by 15 practice trials, 10 of which involved real differences, and consisted of 50 trials. Each subject experienced a total of 270 trials. A summary of the distribution of the 270 trials for the nine conditions experienced by each subject, i.e. anchors preceding, interpolated, and following the comparison stimuli, as well

as three conditions of start and end location variability, is given in Table 4.

The three anchors used were 10 cm, 15 cm and 20 cm lengths, and each of these occurred a total of 90 times. The three anchor positions were each used a total of 30 times, and the six possible number combinations (i.e. 3 vs. 1, 3 vs. 2, 2 vs. 1, 2 vs. 3, 1 vs. 3, and 1 vs. 2) each occurred a total of 45 times. These were all separately randomized. Randomization was attained through random number generation on a PDP 11 computer.

Data Analysis

In order to make the K1 vs. K2 judgments compatible with the K2 vs. K1 judgments, K1<K2 judgments were converted to proportions and this value subtracted from unity. Thus 0.2 judgments of K1<K2 were equivalent to a proportion of 0.8 K2<K1 judgments.

The adjusted data for the proportion of judgments K2<K1 for all conditions, each anchor, and both orders of judgment are given in Tables 5, 6, and 7.

Results

The data were submitted to a repeated measures analysis of variance: 3 (location condition) X 2 (order of judgment) X 3 (anchor size) X 3 (anchor position). The main effect of anchor size was found to be significant, $F(1,16) = 6.92$, $p < .05$.

None of the interactions involving the order of

Table 4

Distribution of Trials Among
the Nine Conditions

No. of Trials	Start and End Point Location	Comparisons
	Condition 1	
30	Preceding (P) = AKK	3 vs. 2; 2 vs. 3
30	Interpolated (I)= KAK	3 vs. 1; 1 vs. 3
30	Following (F) = KKA	2 vs. 1; 1 vs. 2
	Condition 2	
30	AKK	3 vs. 2; 2 vs. 3
30	KAK	3 vs. 1; 1 vs. 3
30	KKA	2 vs. 1; 1 vs. 2
	Condition 3	
30	AKK	3 vs. 2; 2 vs. 3
30	KAK	3 vs. 1; 1 vs. 3
30	KKA	2 vs. 1; 1 vs. 2

NOTE: K = Standard and comparision stimuli

A = Anchor

Table 5

The Proportion of Judgments K2<K1 for Each Subject Under Each Condition of Location Condition 1

Condition	Subject	K2 vs. K1: 10	K2 vs. K1: 15	K2 vs. K1: 20	K1 vs. K2: 10	K1 vs. K2: 15	K1 vs. K2: 20
		LOCATION VARIABILITY CONDITION 1					
		ORDER OF JUDGMENT					
		K2 vs. K1			K1 vs. K2		
		ANCHOR SIZE (cm).			ANCHOR SIZE (cm).		
		10	15	20	10	15	20
Preceeding	1	.60	.80	.60	.40	.80	.40
	2	.00	.40	.40	.20	.20	.20
	3	.40	.60	.20	.40	.80	.20
	4	.40	.40	.60	.80	.20	.20
	5	.20	.40	.20	.00	.00	.60
	6	.40	.20	.40	.20	.20	.20
	7	.20	.60	.40	.20	.20	.20
	8	.40	.40	.60	.00	.40	.60
	9	.20	.00	.40	.20	.20	.20
	$\bar{x}$	.31	.42	.42	.28	.33	.31
Interpolated	1	.80	1.00	.60	1.00	.40	.80
	2	.20	.20	.00	.00	.40	.20
	3	.40	.40	.40	.20	.40	.20
	4	.40	.40	.60	.40	.60	.20
	5	.80	.40	.40	.00	.20	.60
	6	.20	.40	.20	.20	.40	.80
	7	.40	.80	.40	.80	1.00	1.00
	8	.40	.20	.20	.20	.00	.80
	9	.00	.20	.60	.40	.60	.40
	$\bar{x}$	.40	.44	.38	.36	.42	.56
Following	1	.80	.80	.80	.60	.20	.20
	2	.40	.20	.60	.40	.20	.40
	3	.40	.80	.40	.40	.20	.60
	4	.60	.60	.40	.40	.40	.20
	5	.40	.40	.40	.60	.40	.40
	6	.20	.20	.60	.40	.40	.40
	7	.80	.80	.80	.60	1.00	.60
	8	.00	.20	.20	.60	.20	.40
	9	.20	.60	.60	.20	.40	.00
	$\bar{x}$	.42	.51	.53	.48	.38	.36

Table 6

The Proportion of Judgments K2 vs K1 for Each Subject Under Each Condition of Location Condition 2

Condition	Subject	LOCATION VARIABILITY CONDITION 2 ORDER OF JUDGMENT K2 vs. K1 ANCHOR SIZE (cm). 10	15	20	K1 vs. K2 ANCHOR SIZE (cm). 10	15	20
Preceeding	1	.40	.40	.80	.80	.40	.60
	2	.40	.40	.40	.00	.20	.40
	3	.40	.60	.60	.60	.40	.40
	4	.40	.60	.40	.40	.20	.00
	5	.40	.60	.20	.40	.80	.60
	6	.40	.20	.40	.60	.20	.60
	7	.40	.40	.60	.60	1.00	.80
	8	.40	.20	.60	.60	.20	.40
	9	.80	.40	.40	.40	.20	.20
	$\bar{x}$	.44	.42	.49	.49	.40	.44
Interpolated	1	.60	.60	.60	.60	.80	1.00
	2	.00	.20	.40	.20	.40	.60
	3	.00	.60	.80	.00	.20	.60
	4	.20	.00	.60	.20	.40	.80
	5	.20	.20	.20	.40	.20	1.00
	6	.60	.80	.20	.40	.60	.40
	7	.60	.60	.80	.80	.80	.80
	8	.40	.40	.80	.00	.60	.40
	9	.40	.60	.00	.20	.20	.60
	$\bar{x}$	.33	.44	.49	.31	.47	.69
Following	1	.80	.80	.40	1.00	.80	.40
	2	.40	.20	.20	.00	.40	.00
	3	.40	.60	.40	.40	.20	.00
	4	.20	1.00	.40	.80	.60	.00
	5	.20	.60	.40	.20	.40	.20
	6	.40	.40	.40	.40	.60	.20
	7	.80	.40	.80	.80	1.00	.60
	8	.60	.60	.60	.20	.40	.00
	9	.40	.20	.80	.40	.60	.00
	$\bar{x}$	.47	.53	.49	.47	.56	.16

Table 7

The Proportion of Judgments K2‹K1 for Each Subject Under Each Condition of Location Condition 3

Condition	Subject	LOCATION VARIABILITY CONDITION 3					
		ORDER OF JUDGEMENT					
		K2 vs. K1			K1 vs. K2		
		ANCHOR SIZE (cm).			ANCHOR SIZE (cm).		
		10	15	20	10	15	20
Preceeding	1	.80	.40	.80	.20	.60	.40
	2	.60	.80	.60	.40	.40	.40
	3	.60	.20	.40	.80	.00	.20
	4	.60	.40	.60	.20	.40	.40
	5	.00	.00	.60	.60	1.00	.40
	6	.80	.80	.40	.40	.20	.60
	7	.20	.20	1.00	.60	.60	.80
	8	.40	.80	.60	.40	.40	.20
	9	.60	.60	1.00	.40	.60	.60
	$\bar{x}$	.51	.48	.67	.44	.47	.44
Interpolated	1	.80	.60	1.00	.40	.40	.80
	2	.40	.80	1.00	.40	.40	.40
	3	.40	.40	.20	.20	.60	.40
	4	.20	.40	.80	.20	1.00	1.00
	5	.20	.40	.20	.20	.40	.40
	6	.80	.60	.40	.40	.40	.60
	7	.60	.40	.60	.80	.60	.40
	8	.60	.40	.20	.40	.40	.40
	9	.60	.60	.20	.00	.20	.40
	$\bar{x}$	.51	.51	.51	.33	.47	.53
Following	1	.80	.80	.80	.60	.40	1.00
	2	.80	.20	.60	.40	.40	.80
	3	.40	.20	.40	.20	.00	.40
	4	.40	.60	.80	.80	.20	.40
	5	.00	.20	.20	.00	.60	.60
	6	.40	.20	.60	.00	.00	.20
	7	.60	1.00	.40	.80	.80	.80
	8	.80	.40	.80	.60	.80	.60
	9	.60	.20	.60	.40	.20	.60
	$\bar{x}$	.53	.42	.58	.42	.38	.60

presentation factor were significant, consequently the proportion data were collapsed over this factor, and each condition further analyzed for anchor effects using Tukey's test on means. The results of the analysis were that for location condition 2 (start position constant: end location variable) the proportion of judgments K2<K1 with an interpolated anchor (KAK) of 20 cm, were significantly higher than the proportion of K2<K1 judgments for the small 10 cm interpolated anchor condition. Also under location condition 2, the proportion of K2<K1 judgments with a following anchor (KKA) of 20 cm were significantly lower than the proportion of K2<K1 judgments with a 15 cm anchor in the same following condition. All other comparisons were nonsignificant. Location conditions 1 and 3 did not provide significant anchor effects.

The proportion of judgments K2<K1, collapsed across order of presentation factor, for all three start and end location conditions, are illustrated in Figures 8, 9, and 10.

The proportion of judgments K2<K1, collapsed across both order of presentation factor and the three start and end location conditions, is illustrated in Figure 11.

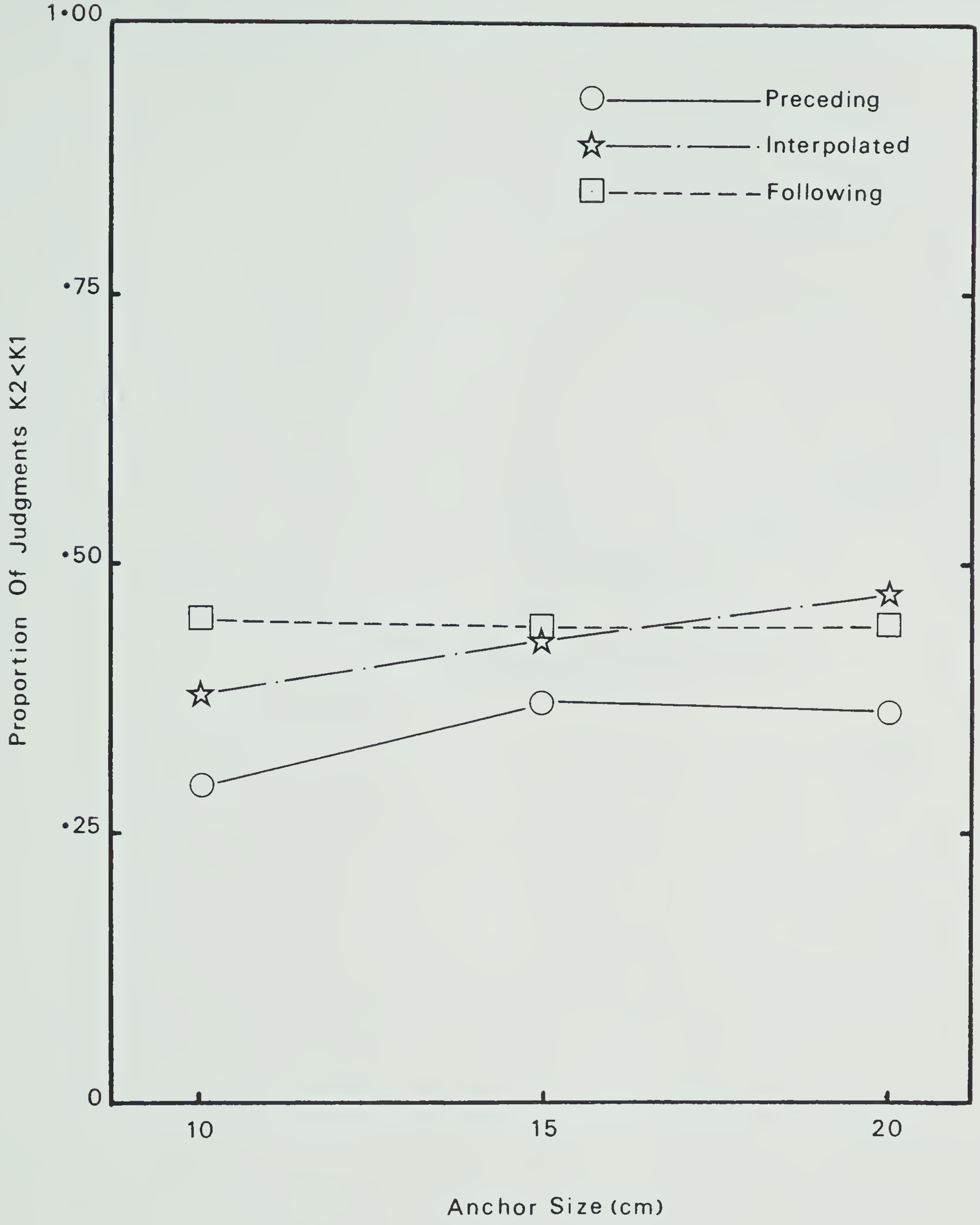


Figure 8. The proportion of judgments K2<K1 at each anchor level (collapsed across order condition) for the three anchor positions: P (preceding), I (interpolated), and F (following). For location condition 1.

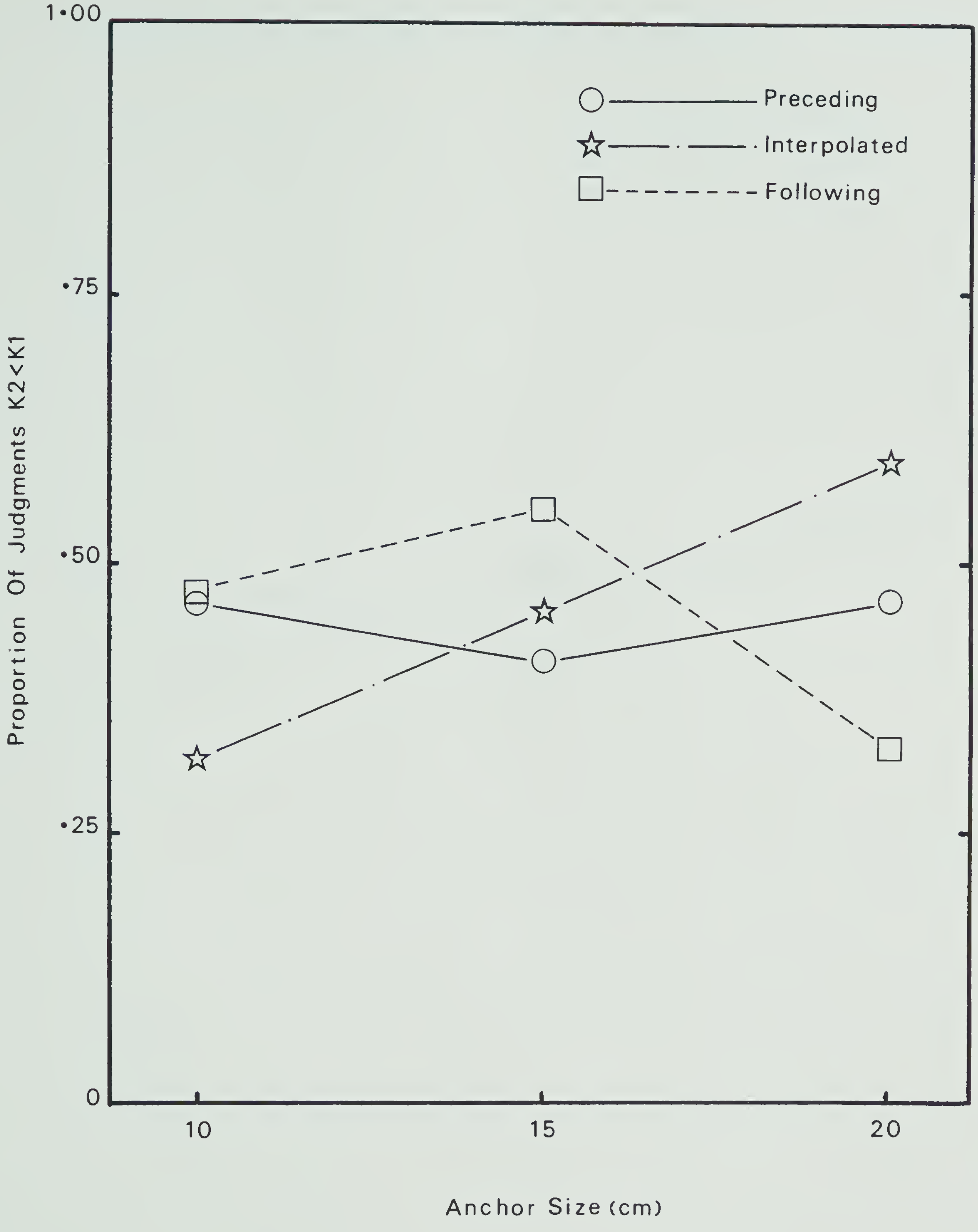


Figure 9. The proportion of judgments K2<K1 at each anchor level (collapsed across order condition) for the three anchor positions: P (preceding), I (interpolated), and F (following). For location condition 2.

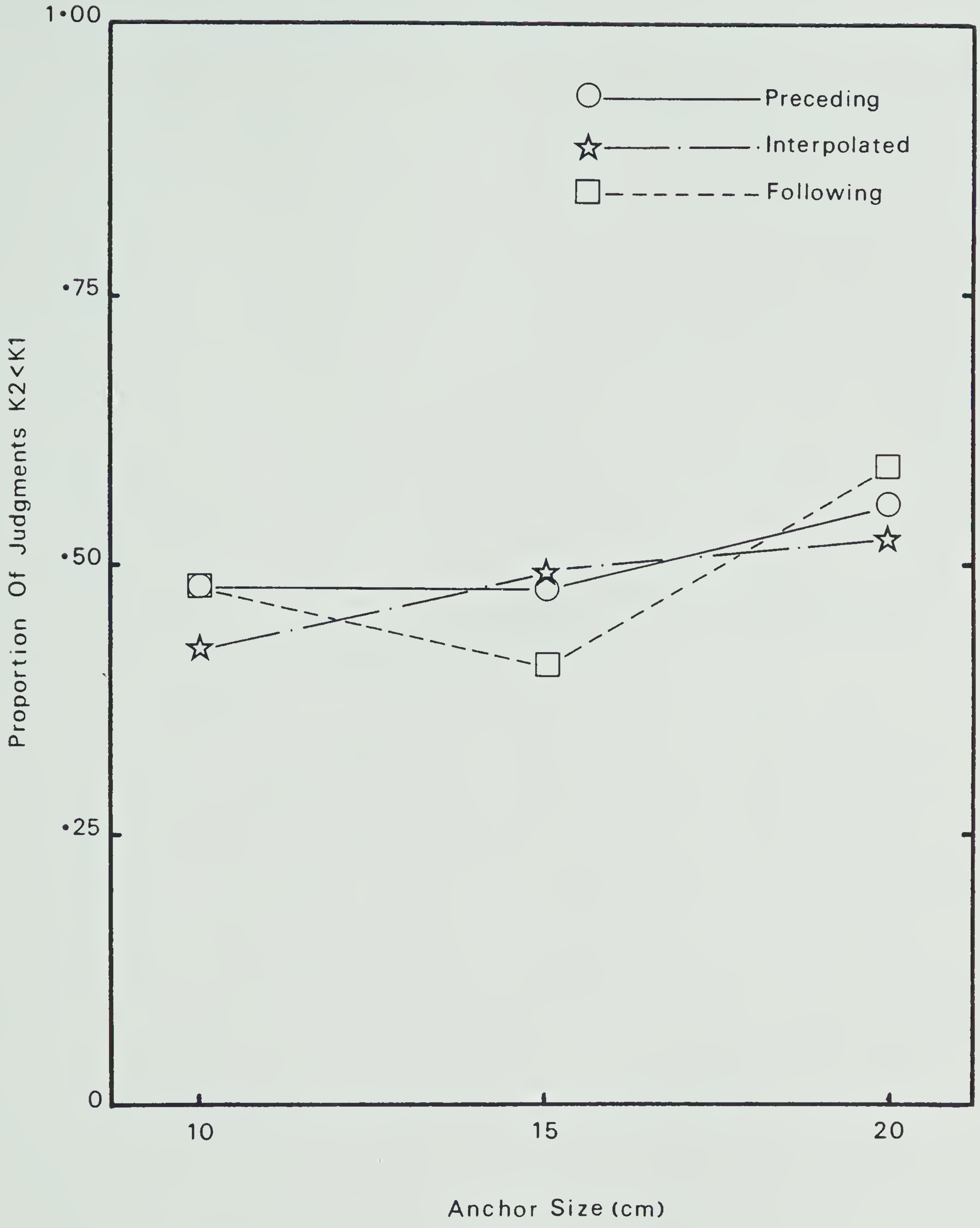


Figure 10. The proportion of judgments K2<K1 at each anchor level (collapsed across order condition) for the three anchor positions: P (preceding), I (interpolated), and F (following). For location condition 3.

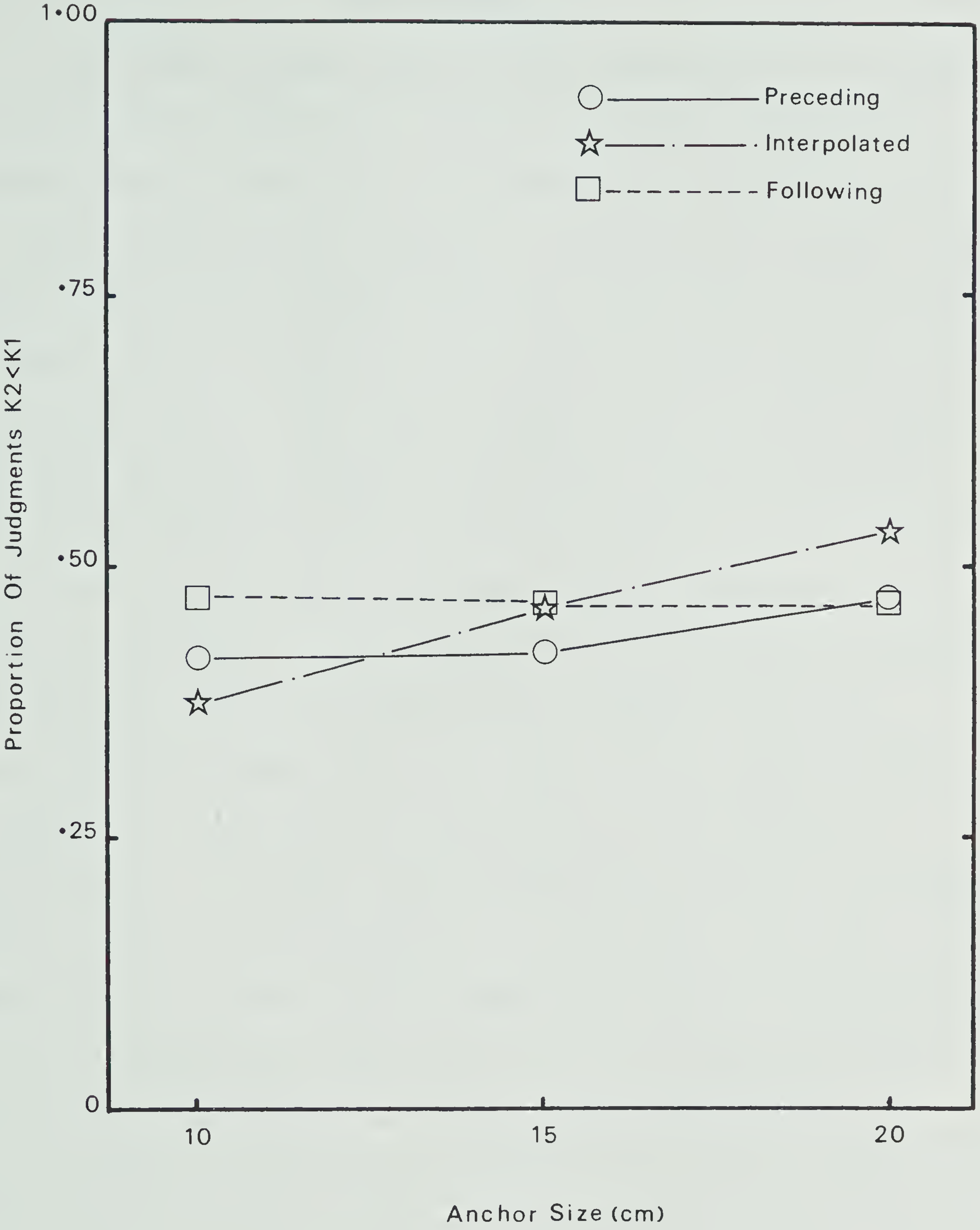


Figure 11. The proportion of judgments K2<K1 at each anchor level (collapsed across both order condition and location start and end condition) for the three anchor positions: P (preceding), I (interpolated), and F (following).

Discussion

The anchor stimuli did provide significant directional biasing but not under all conditions tested. Significant anchor effects were only in evidence for location condition 2 (start location held constant: end location varied), and even within this location condition significant directional biasing did not occur for all anchor sizes and anchor positions tested. The interpolated anchor position (KAK) provided the most conducive and stable biasing condition for anchor effects within location condition 2. The long and short anchors provided significantly different proportion of K2<K1 judgments in the interpolated condition. Although the long and short anchor judgments did not significantly differ from the 15 cm control anchor (KKK) judgments in the interpolated condition, for location condition 2, all three anchor movements produced the stable linear directional biasing trend associated with the theories of context effects (see Figure 10). Unfortunately in the interpolated condition (KAK) it is impossible to say whether the significant directional biasing was attributable to retroactive assimilation effects (Helson, 1964) or proactive contrast effects (Ellis, 1971, 1973a), as both models predict the same biasing effects for this condition.

When the anchor stimulus followed the standard and comparison stimuli (KKA) in location condition 2, the long anchor produced significantly lower proportion of judgments K2<K1 than did the control (15 cm) anchor. This position

coincides with retroactive assimilation theory; however, the long anchor proportions did not significantly differ from the small anchor proportions in the following (KKA) condition. Indeed, both the short and long anchors produced lower proportion of K2<K1 judgments, than did the control anchor in the following (KKA) condition, which does not fit into an assimilation or contrast theory.

Location condition 1 replicated the conditions tested in Experiment 1. Again the directional biasing effects were nonsignificant. Similar results were found for location condition 3.

Considering all three location conditions tested, two consistencies are noteworthy. First, the interpolated condition (KAK) produced consistent results throughout. Although only producing significant directional biasing in location condition 2, the same linear trend was evident in all three location conditions. Secondly, there appears to have been a negative time-error involved in this study. The proportion of judgments K2<K1 lie below 0.5 in nearly all conditions tested. There was a bias toward judging the second stimulus (K2) to be longer than the first (K1). This bias is especially evident in the control anchor (KKK) condition, where, in general, there was negligible anchor effects, but nevertheless all proportion judgments remained under the 0.5 (chance) level (see Figure 11).

Overall the stability of location start point and end point was an important factor in determining directional

biasing with the linear arm movements tested in this study. Under similar movement lengths, location condition 2 provided significant directional biasing effects whereas location positions 1 and 3 did not.

Laabs (1974) considered the effect of interpolated movements on criterion movement recall, and assessed separately both distance and end location. He found that the lengths of the interpolated anchors caused an assimilation effect for distance reproduction and that end locations of interpolated anchors caused an assimilation effect for location reproduction. In the present study when location cues were made unreliable in location condition 3, distance recognition was not significantly biased by anchor movements. One possible explanation for the ineffectiveness of anchor movements to bias recognition judgments in location condition 3, may have been the procedure used in this condition. Keeping location start and end points unreliable required subjects to make movements at different positions along the slide bar. Within a trial, subjects had to release hold of the hand slide after each movement presentation and then have their hand manually directed to the new start location to receive the next movement length. Such additional interfering movements and distractions of attention may have contributed to the lack of directional biasing observed in location condition 3.

Anchor movements were also ineffective in biasing recognition judgments when the end location point was made

a reliable cue in location condition 1. However, when the start location was made the reliable cue in location condition 2, significant directional biasing in recognition occurred. The location start point and end point stability was therefore an important factor in the retention of the movement information. A possible reason for the differential biasing results observed in location conditions 1 and 2, is the relative strength of memorial cues used to encode the movement information in these two conditions. A reliable end location may provide a strong memorial cue (Tannis, 1977) which assists in the accurate recognition of movement items. Keeping start location reliable and allowing end location to vary may not provide such strong memorial cues, thus allowing interference effects from additional anchor movements.

The present study and earlier comparisons of distance - location interference (Gundry, 1975; Kerr, 1978; Laabs, 1971, 1973, 1974; Stelmach & Kelso, 1973) support the notion that a variety of factors within the movement context affect short-term motor retention. Unfortunately to isolate and remember one movement parameter (e.g. distance) exclusive of other parameters present in the movement is extremely difficult (Laabs, 1974). Adequately separating distance cues from location cues is a methodological problem, and recently such methods to do so have come under criticism (Kerr, 1978).

The finding, under all conditions, that it does not

make any difference whether judgments are made K1 relative to K2, or K2 to K1, further substantiates the similar findings in Experiment 1, and is at variance with the adaptation-level theory set forth by Michels and Helson (1954). According to Michels and Helson, when the order of presentation of the standard stimulus and the comparison stimulus is reversed, a new relation between judgment and stimuli is found. This was not the case in Experiments 1 and 2 when judgments of two equally long motor movements were made. Judgments of K1 vs. K2 were no different from judgments of K2 vs. K1.

EXPERIMENT 3

The Effect of Anchor Stimuli on Movement Recognition and Movement Recall

It was not possible to determine whether retroactive assimilation (Helson, 1964) or proactive contrast (Ellis, 1971, 1973a) was the primary cause of the anchor biasing effects in Experiment 2. This was due in part to the anchors producing nonsignificant and non-linear biasing trends in the preceding (AKK) and following (KKA) conditions. The significant directional biasing found with the interpolated (KAK) condition can be interpreted from both an assimilation and contrast viewpoint as both predict the same judgmental outcome for this KAK condition.

Directional biasing effects due to anchor stimuli were in evidence in Experiment 2. However, not all conditions tested elicited significant directional biasing effects. Limited directional biasing occurred in Experiments 1 and 2 when a standard movement of 15 cm was presented in context with anchor movements 5 cm shorter and 5 cm longer than the standard movement. Such anchor stimuli had only limited significant biasing effects on the *recognition* of movement length judgmental process. This would seem to be in disagreement with the findings of other MSTM researchers who have consistently reported significant directional biasing effects due to anchor stimuli (Gundry, 1975; Laabs, 1971, 1973, 1974; Patrick, 1971; Stelmach & Walsh, 1973). However, this difference may be due to the particular

research paradigms employed. Context effects in MSTM research have mainly been studied through *recall* paradigms, with a subject typically being asked to reproduce a criterion movement. Consistent directional biasing did not occur with all anchor conditions tested in Experiments 1 and 2 analyzed via a *recognition* paradigm.

Further differences between the first two experiments and previous MSTM context effect research can be seen in the type of motor task employed. The majority of MSTM experiments have been conducted using radial arm movements. Only a very few have utlized linear movements. The possibility therefore exists that directional biasing may not only be caused by anchor stimuli but may also be influenced by the type of motor task used. Before this possibility can be tested, it would be necessary to determine whether or not the linear movement lengths employed in Experiments 1 and 2 could produce directional biasing when a recall paradigm is employed. The following experiment tested the affects of such anchor stimuli on movement recall. Directional biasing effects were analyzed by using a recall paradigm based on a technique known as the psychophysical method of adjustment.

With a recall paradigm, the accepted dependent variables in MSTM are related to errors in reproduction of the criterion movement. Absolute Error (AE), Constant Error (CE) and Variable Error (VE) singly and in combination, have all been used as measures of recall fidelity. To have an error score one must first have a standard for comparison.

Owing to individual differences, subjects will differ in their ability to accurately recall a movement length. For example, Holzman (1954) and Holzman and Klein (1954) considered the cognitive style dimension of 'sharpening' and 'levelling'. Sharpening refers "to a propensity to maximize stimulus differences, an attunement to small gradients of differences between figure and ground. People who level tend to minimize such differences and to prefer the experience of sameness to that of difference" (Holzman, 1954, p. 376). Holzman concluded from his studies that levellers are more susceptible to the influence of anchor stimuli interpolated between standard and comparison items. To account for such individual differences the following experiment included 40 trials for reproduction of the standard movement in the absence of an anchor stimulus.

The nature of a KA and AK condition requires recall of K after different retention intervals. Adams and Dijikstra (1966) showed that AE in repeating a blind positioning movement was a function of the duration of a unfilled retention interval. Thus recalling K in a KA condition will probably be inferior to recalling K in a AK condition due to the longer retention time between K and recall in the KA condition. To account for this retention time difference, the initial 40 trials included two appropriate retention times.

Accurate measurement of reproduction was necessary in the following experiment and so a different slide bar to that employed in previous experiments was used. For this reason the KAK recognition paradigm, previously tested in Experiments 1 and 2, was re-tested.

It could be asserted in Experiments 1 and 2 that anchor stimuli not sufficiently different from the standard and comparison stimuli were the reason for a lack of directional biasing. In addition to the three sizes of anchor movement used in Experiments 1 and 2, a fourth anchor movement, considerably longer (25 cm) than the standard (15 cm) and comparison (15 cm) movements, was employed in the following experiment to test this hypothesis.

Finally, in the area of psychophysical judgments Brown (1953), Ellis (1971), Gleitman and Hay (1964), and Kind and Brown (1966) have all reported diminished assimilation effects when a subject became aware of the stimulus which was to be judged the anchor. When a subject became aware as to which of the two stimuli he was to compare, even though he was presented a third, he had the ability to somehow drop the third from his judgmental processing, and thereby affect the assimilation process (Kind & Brown, 1966). It is therefore possible that subjects in both Experiments 1 and 2 were able to discount the anchor stimuli when making a judgment. Subjects were always asked to compare K1 and K2, and decisions relative to the anchor were not requested. The inclusion of trials

wherein subjects were to make comparisons using K1 and K2 with the anchor (catch trials) would have alleviated any possibility of dropping the anchor stimuli from the judgmental processing.

The following experiment utilized another method to ensure that a subject would consider all stimuli in his judgmental processing. Recognition and recall trials were randomly ordered. Subjects were postcued to make a recall after receiving two movement lengths, or were postcued to make a recognition judgment after receiving three movement lengths. A subject was therefore required to remember both the first two movement lengths as there was a likelihood that he would be required to recall either one of them. There was also a likelihood that he would receive a third movement length for recognition purposes. A subject was therefore required to remember all three movement lengths.

Judgments of K1 vs. K2 were not found to significantly differ from judgments of K2 vs. K1 in the two previous experiments. Only judgments of K1 vs. K2 were therefore requested in the following experiment.

In Experiment 2 directional biasing effects due to anchor stimuli were at a premium in location condition 2. This condition, where start location remained constant with the end location being varied for movement item presentation, was adhered to in Experiment 3.

Method

Subjects

Five male and four female subjects (aged 23-31 years) voluntarily participated in this experiment. The nine subjects were graduate students who wrote with their right hand.

Apparatus and Task

A meter bar (uncalibrated) mounted on a dexion frame served as a track along which the subjects produced linear movement distances by moving a cursor with a metal handle. The cursor was attached to a 10-turn potentiometer (1 KΩ) from which the output, after passing through a voltage divider/amplifier box, was connected to a digital multimeter (Fluke 8000A). When the cursor was moved, the distance traversed was recorded in mv on the digital multimeter. The digitized voltage was then converted to its movement distance equivalent in cm.

The subject sat comfortably in front of the apparatus wearing a blindfold and moved the cursor horizontally from the right to the left with his right hand. The experimenter set the length of the distances with a mechanical stop that was mounted adjacent to the track.

The experiment was controlled in exactly the same way as in Experiments 1 and 2, but this time the repetitive tone cycle was provided by two Hunter Timers (model E). The stimulus movement duration was standardized at 3 seconds

and the interstimulus interval at 6 seconds. Time between trials was approximately 30 seconds.

Design

The experimental design was a 2x2x4 factorial with repeated measures on all factors. The first factor was 2 levels of subject response; recognition and reproduction (recall). The second factor was two levels of anchor position: presentation of A before K, and presentation of A following K. The third factor was four levels of anchor size; namely, anchor lengths of 10 cm, 15 cm, 20 cm, and 25 cm. Each subject received five trials for each of the randomly presented conditions.

Procedure

The subject was presented a criterion distance by having him actively move the cursor from a fixed start position to a stop. The same three tone sequence of 'grasp hold', 'move', and 'release' as used in Experiments 1 and 2, was used for movement presentation. When a further tone signified the end of the retention interval, the subject regrasped the cursor handle and reproduced the criterion move. After the reproduction, the distance was recorded to the nearest mm. Two retention intervals were used, 3 seconds and 12 seconds. The criterion distance was set at 15 cm and each subject received 40 trials (20 for each retention interval).

The subject was next presented with either two or three movement lengths within one trial. When two

movement lengths were presented the subject was verbally postcued "reproduce one" or "reproduce two". The subject regrasped the cursor handle and reproduced the requested movement. When three movement lengths were presented the subject made a recognition judgment on comparison lengths. The subject was verbally postcued "one versus three" or "two versus three". The subjects made a verbal response of "same" or "different". A "different" response was followed by an indication of the difference.

The first session was preceded by 20 practice trials, 10 of which involved real differences so the experimenter could note if subjects had failed to grasp the procedure. The pre-training was successful in that no subject required remedial training.

The second session (held on a subsequent day) was preceded by 10 practice trials, five of which involved real differences. Each session consisted of 40 trials. The distribution of the 80 trials is summarized in Table 8.

The movement stimuli K1 and K2 were each set at 15 cm. The four anchor lengths used were 10 cm, 15 cm, 20 cm, and 25 cm, and each of these occurred a total of 20 times (10 each session). Of the 80 trials, 40 involved recognition judgments (K1 vs. K2), and 40 involved recall of the standard stimulus (K1).

The 80 trials were separately randomized.

Table 8

Distribution of Trials Among the Four Conditions

No. of Trials	Condition	Task
20	KA	Recall K
20	AK	Recall K
20	KAK	Compare 1 vs. 3
20	AKK	Compare 2 vs. 3

Note: K = Standard and Comparison Stimuli
A = Anchor Stimulus

<u>Data Analysis</u>

To compare the recognition judgments with the recall data, a compatible scale of judgment was devised. A rating scale of +1, 0, or -1, was administered to both recognition and recall data.

Judgments of K1>K2 received a +1, judgments of K1<K2 received a -1, and judgments of K1=K2(same) received a zero. With five trials for any one condition tested, a rating could therefore vary from +5 to -5, depending on the judgments made.

The reduction of recall data to the devised scale was a little more complex. The recall of K occurred 3 seconds after presentation in the AK condition, but after 12 seconds in the KA condition. To alleviate this bias, a subject's ability to recall K after 3 seconds and after 12 seconds, in the absence of anchor stimuli, was recorded for 20 trials. The means and standard deviations were calculated for the final 10 trials of each condition. Two standard deviations above and below the means were taken to represent judgments of K1=K2(same) for the respective AK and KA conditions. Recall values within this bandwidth were allocated zero scores. Recall values greater than two standard deviations (.05 level) received a +1 rating, and recall values less than two standard deviations received a -1 rating, with respect to the appropriate AK and KA conditions.

The recognition and recall data, reduced to the devised scale are given in Tables 9 and 10 respectively.

Table 9

Transformed Recognition Data

S	ORDER							
	KAK				AKK			
	ANCHOR SIZE (cm)				ANCHOR SIZE (cm)			
	10	15	20	25	10	15	20	25
1	-1	4	1	5	1	-1	3	3
2	0	3	-1	-1	-3	4	3	-1
3	-1	-1	-1	-3	-1	0	-1	-2
4	-2	3	-1	-2	-3	2	5	3
5	1	-1	5	3	-2	2	3	5
6	-1	3	4	4	2	0	0	1
7	2	-1	1	-1	-3	-4	1	1
8	1	3	2	3	1	1	2	3
9	1	-2	-1	0	-2	-2	-2	0
$\bar{x}$	0	1	1	0.9	-1.1	0.2	1.6	1.4

NOTE: K = Standard and Comparison Stimuli

A = Anchor Stimulus

S = Subject

Table 10

Transformed Recall Data

S	ORDER							
	KAK				AKK			
	ANCHOR SIZE (cm)				ANCHOR SIZE (cm)			
	10	15	20	25	10	15	20	25
1	1	4	3	-1	0	-1	1	0
2	0	0	1	1	-1	0	2	4
3	0	1	0	2	1	0	0	1
4	-1	-3	-4	-3	0	-1	1	-1
5	-2	-1	-1	0	1	-1	0	4
6	1	0	0	-1	1	2	0	1
7	-3	0	-3	0	-2	0	0	0
8	-4	-2	2	0	0	-1	1	0
9	1	0	-1	0	0	0	-1	-1
$\bar{x}$	-0.8	-0.1	-0.3	-0.2	0	-0.2	0.4	0.9

NOTE: K = Standard Stimulus

A = Anchor Stimulus

S = Subject

The means for the final 10 trials of recalled K without anchor stimuli were used as standards to calculate CE scores. The recall data for the AK and KA conditions were compared against the appropriate mean to elicit CE and VE scores.

The recall CE and VE scores are given in Tables 11 and 12 respectively.

Results

The recognition and recall data were submitted to a repeated measures analysis of variance: 2 (recognition vs. recall) X 2 (anchor position) X 4 (anchor size). The main effect of anchor size was found to be significant, $F(1,8) = 4.73$, $p < .065$, conservative F test, $F(3,24) = 4.73$, $p < .01$, normal F test. No other main effects or interactions were significant.

Analysis of the transformed data results provided a significant anchor effect with a conservative test at the .065 level of significance. The Greenhouse and Geiser (1959) conservative F test for repeated measures designs can be unfairly biased towards Type II errors, consequently consideration was given to the normal F test.

Analysis of the transformed data results with a normal F test produced a significant anchor effect at the .01 level of significance. Each condition was further analyzed for anchor effects using Tukey's test on means. The results of the analysis were that significant directional

Table 11

Recall Constant Error Data (cm)

S	ORDER							
	KA				AK			
	ANCHOR SIZE (cm)				ANCHOR SIZE (cm)			
	10	15	20	25	10	15	20	25
1	+0.74	+1.60	+1.40	+0.08	+0.47	-0.18	+0.13	+0.42
2	-0.05	-0.70	-0.35	-0.14	-1.08	-0.85	-0.10	+0.27
3	+1.02	+0.45	-0.32	+1.93	+1.12	+0.47	+0.38	+0.40
4	-1.21	-2.33	-2.53	-1.93	-0.21	-1.22	-0.93	-0.06
5	-1.82	-0.36	-1.93	+0.04	+0.61	+0.01	+0.68	+1.78
6	+2.36	-0.03	-0.25	-0.06	+2.25	+1.64	+0.58	+1.01
7	-1.49	-0.45	-1.78	+0.10	-2.52	-1.37	-1.27	-1.02
8	-1.12	-0.38	+0.87	+0.69	-0.84	-1.38	+0.31	-0.78
9	+0.83	-0.13	+0.26	+1.46	-1.43	-1.13	-1.54	-1.79
$\bar{x}$	-0.08	-0.26	-0.51	+0.24	-0.18	-0.45	-0.20	+0.03

NOTE: K = Standard Stimulus
A = Anchor Stimulus
S = Subject

Table 12

Recall Variable Error Data

S	ORDER							
	KA				AK			
	ANCHOR SIZE (cm)				ANCHOR SIZE (cm)			
	10	15	20	25	10	15	20	25
1	0.98	0.69	0.86	1.51	0.55	1.21	1.13	0.63
2	0.80	1.36	0.95	1.02	0.98	0.83	1.04	0.63
3	0.55	1.22	0.49	1.42	0.85	0.78	1.81	1.50
4	0.77	1.61	1.15	1.61	1.10	1.57	1.39	1.40
5	1.97	1.28	2.14	0.97	0.99	1.87	0.67	1.18
6	1.07	0.63	1.07	1.65	0.79	2.17	0.44	1.19
7	0.85	0.70	0.67	1.05	1.04	0.35	0.49	0.63
8	1.38	1.35	0.70	1.17	0.80	0.53	1.13	0.52
9	1.59	0.78	1.72	0.34	1.41	1.17	1.28	0.95
$\bar{x}$	1.11	1.01	1.08	1.19	0.95	1.16	1.04	0.96

NOTE: K = Standard Stimulus

A = Anchor Stimulus

S = Subject

biasing occurred for those recognition trials wherein the anchor preceded the standard and comparison stimuli (AKK). In this preceding condition (AKK) both the 20 cm and 25 cm anchor scores were significantly higher ($p < .05$) than the 10 cm anchor scores. All other comparisons were nonsignificant.

The recognition and recall data, reduced to the devised scale, is illustrated in Figure 12.

The recall CE data were submitted to a repeated measures analysis of variance: 2 (anchor position) X 4 (anchor size). None of the main effects or interactions were significant.

The recall VE data were likewise submitted to a similar repeated measures analysis of variance: 2 (anchor position) X 4 (anchor size). None of the main effects or interactions were significant.

The recall CE and VE data, collapsed across order of anchor presentation, is illustrated in Figure 13.

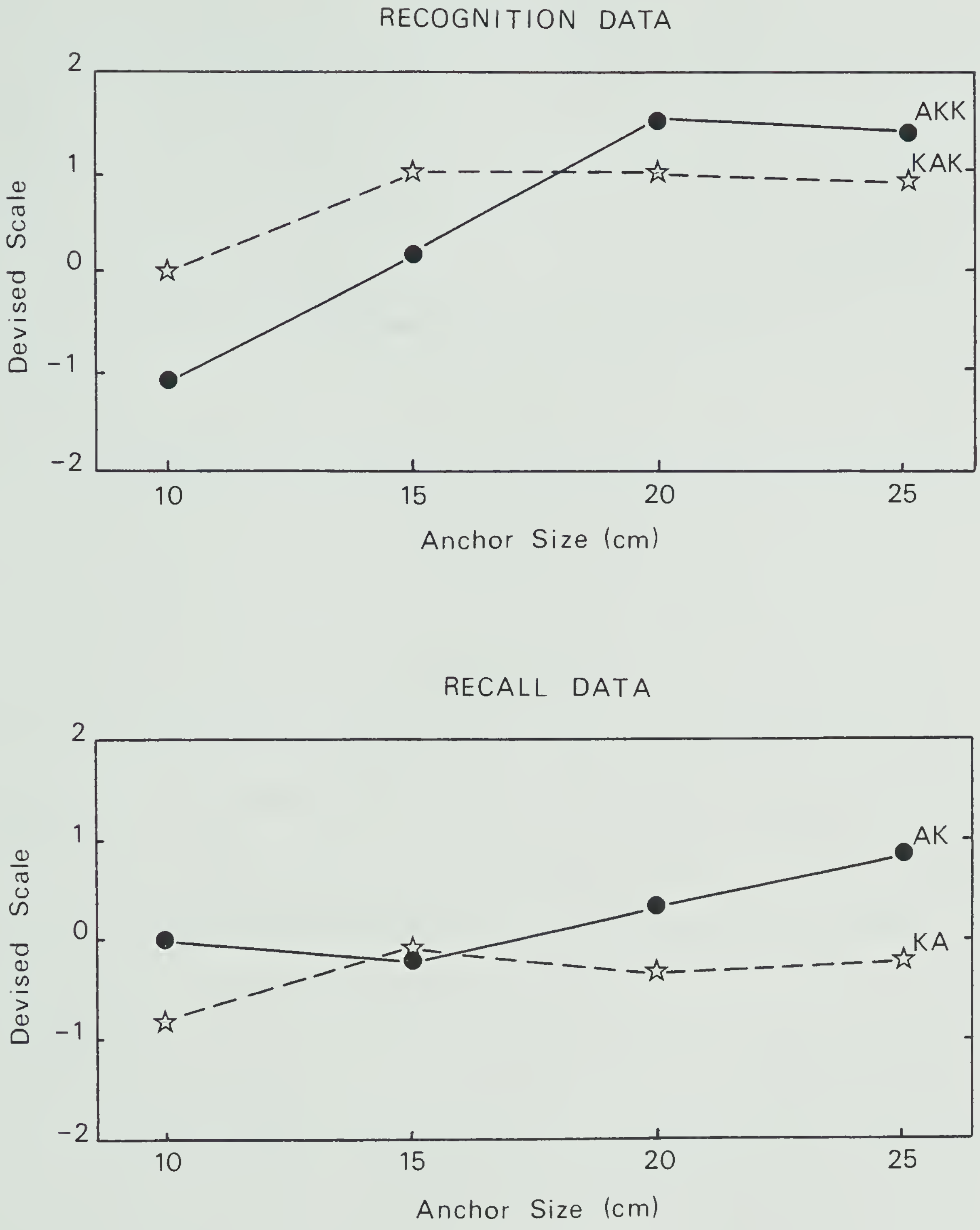


Figure 12. Recognition and recall data transformed to a devised scale.

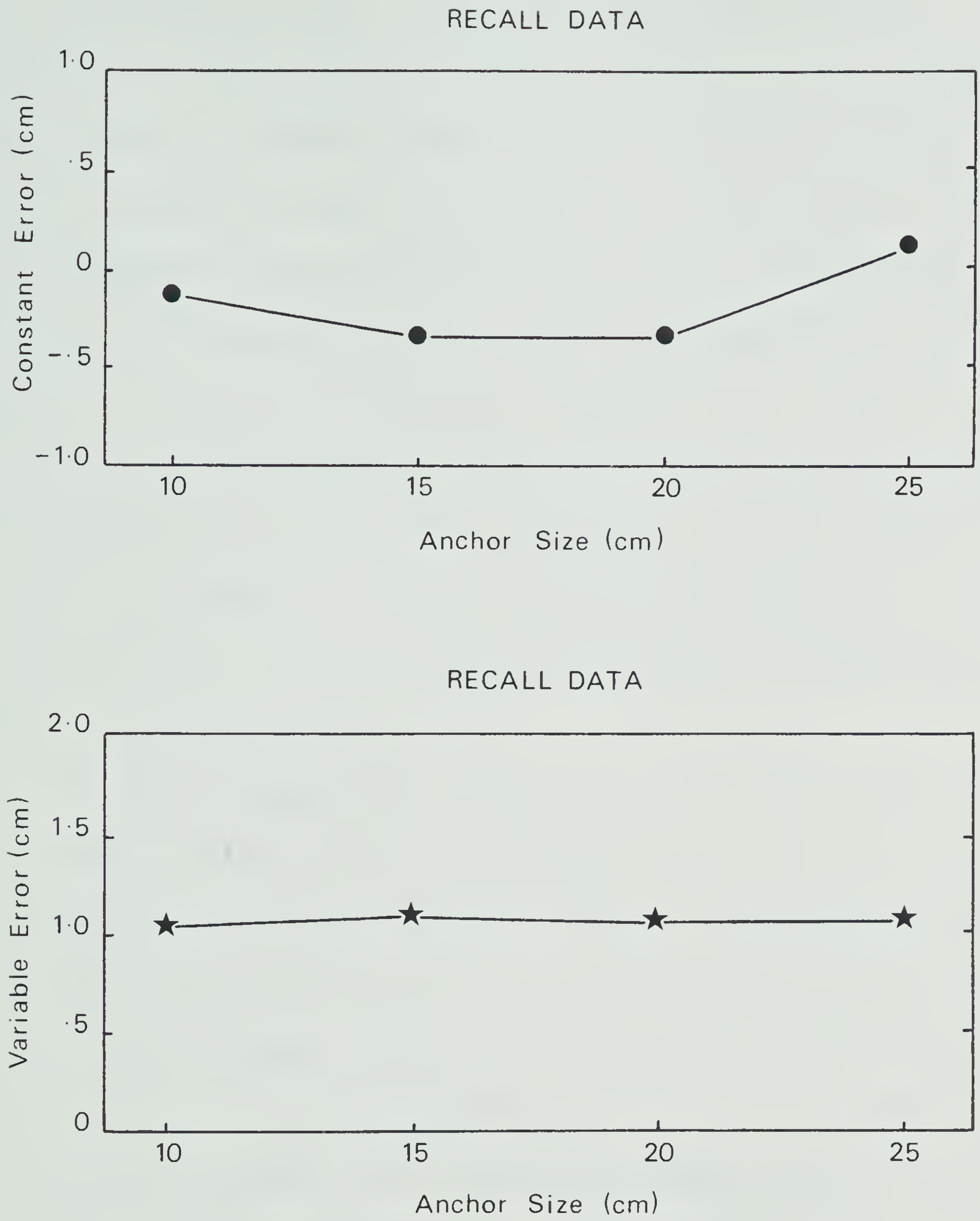


Figure 13. Constant error and variable error (collapsed across order of anchor presentation) for recall of the 15 cm standard.

Discussion

The anchor stimuli again provided significant directional biasing when analyzed through a recognition paradigm. However, significant biasing was only found in the anchor preceding condition (AKK). In Experiments 1 and 2 the preceding condition failed to produce significant directional biasing effects. Indeed, there was very little systematic biasing evident for the AKK condition in either of the previous studies. The interpolated anchor condition (KAK) proved to be the most consistent biasing condition in both Experiments 1 and 2. In this experiment the interpolated condition failed to provide a similar biasing effect (see Figure 12).

The preceding anchor results fit in quite well with retroactive assimilation theory (Helson, 1964); the small 10 cm anchor provided negative directional biasing while the longer 20 cm and 25 cm anchor produced positive directional biasing. Helson's adaptation-level theory would in fact, predict superior positive directional biasing for the 25 cm anchor over the 20 cm anchor when the standard and comparison are both 15 cm. The reverse was actually found in this study (see Figure 12). However, this departure from linearity does not detract from an assimilation interpretation. Ellis' (1971, 1973a) proactive contrast model predicted a reversal in the directional biasing effect to that found in this study under the anchor preceding condition.

Superior directional biasing of preceding anchors over interpolated anchors does not conform with previous research in MSTM. Craft (1973) and Craft and Hindrichs (1971) both report superior assimilation effects when the anchor preceded the standard as opposed to following it. This discrepancy may be due to two reasons. First, both the procedure and method of determining the dependent variable score were unique to this study. Second, Craft's studies involved *recall* procedures requiring storage of two movement items in memory within one trial. This study involved the storage of three movement items in memory within one trial, and then making a *recognition* judgment between two. Comparisons between studies may therefore be unfounded.

Significant directional biasing did not occur in the recall procedure. It is quite possible the method used to reduce the recall data to a compatible scale for comparison with the recognition data may have resulted in a conservative analysis. The recall data were converted to new integer scale values so that comparisons could be made with recognition integer values. This was done on the basis of ±2 standard deviations forming the limit of acceptance of the judgment 'same'. Any recall outside ±2 standard deviations was considered to be a biased judgment. Recalled judgments had to be fairly heavily biased to lie outside ±2 standard deviations as this accounts for more than 95% of the normal distribution. This may have been too stringent

a test and so the recall data were reduced to a scale corresponding to ±1 standard deviations (> 68%). The new ±1 standard deviation data were submitted to a repeated measures analysis of variance, and again nonsignificant main effects and interactions resulted. The failure to find significant directional biasing due to the anchor movement lengths tested in this experiment under a recall procedure, was further borne out by the similar nonsignificant analysis of the recall error data.

The anchor stimuli apparently failed to produce significant directional biasing for the recall condition. This lack of biasing in the recall condition does not conform with previous MSTM research involving context effects. Many studies have reported significant directional biasing due to anchor stimuli (Craft, 1973; Craft & Hindrichs, 1971; Herman & Bailey, 1970, Laabs, 1974; Patrick, 1971, Pepper & Herman, 1970; Stelmach & Walsh, 1972, 1973). Two reasons may be postulated to account for this variance. First, the subjects may have been aware as to which stimuli were being compared each time, and which stimulus was to be recalled; and thus were able to 'drop' the anchor stimuli from memory. The design of Experiment 3 hoped to erradicate this problem by including both a recall and recognition paradigm. However, personal interviews on completion of Experiment 3 revealed this was not the case. Subjects quickly became aware as to which movement length they would be asked to recall as only K and never A was requested.

Similarly, recognition involved the comparison of K1 vs. K2 and never K vs. A. Subjects became aware of this and tended to ignore the longer and shorter anchor movements, and so just concentrated on the standard (K1) and comparison (K2).

Ignoring the anchor stimuli may or may not have affected directional biasing. It was stated earlier that in psychophysical judgments Brown (1953), Gleitman and Hay (1964), and Kind and Brown (1966) all suggest the negating of anchor effects when subjects become aware as to which stimuli is the anchor. MSTM researchers have failed to find this effect. Some of the MSTM studies required the anchor stimuli to be remembered, others did not; yet similar directional biasing effects were found. Craft (1973), and Craft and Hindrich (1971) tested the effects of precuing and postcuing, and concluded that the locus of cuing of the required response at recall does not appear to be a relevant variable in MSTM. This lack of difference between precuing and postcuing of the required response is also at variance with results of studies of verbal short-term memory, where precuing of the response order required at recall typically leads to better recall performance than does postcuing (Hindrichs, 1968). From the finding that advanced knowledge as to which movement is to be recalled offers little benefit to a subject's recall accuracy, it could be suggested that trace intensity interaction takes place at a peripheral rather than a central level, and is not under the direct control of the subject.

This may not be the case however, if consideration is given to VE data in MSTM locus of cuing experiments. Average CE is found to be unaffected by knowledge of postcuing or precuing, but VE is found to change. VE of reproduction increases only when anchor stimuli have to be remembered, and VE is seen as an index of forgetting in MSTM studies (Laabs, 1979).

The relevancy of judging anchor stimuli is a difficult question. Although Helson (1964) claimed that, "we would not expect stimuli to be as effective when subjects are merely allowed to see or observe them as when they are called upon to discriminate, judge or remember them" (P. 143), he does not offer any reason for doubting the efficacy of unjudged anchors. Reasons which readily spring to mind are the anchors, if unjudged, may not be considered relevant to the situation; and/or they might receive less attention, and consequently be less effective.

It is worth noting that, in the first published experiment involving the method of constant stimuli with interpolated anchors, Guilford and Park (1931) observed that the interpolated anchor effects diminished over time, and that subjects reported that the anchor stimuli seemed to "drop out". In Guilford and Park's study judgments of anchor stimuli were not made - nor, indeed, were they included in any of the similar studies in the 1930's. The 'dropping out' found by Guilford and Park seemed to occur for sophisticated subjects (one of whom was Guilford

himself, and another a psychology graduate), which corresponds with the later finding, by Engen and Tulaney (1957), that sophisticated subjects are less susceptible to context effects that naive subjects.

Lastly, Ellis (1971) considered the question "Does non-judgment of the interpolated anchor stimuli give a different psychometric function to that when anchors are judged?" (p. 92). Employing auditorystimuli Ellis found that unjudged anchors are less effective only at the lower end of the anchor scale. This may be interpreted as meaning that the instructions not to judge the anchor stimuli were effective in diminishing only the effects of softer anchors. This diminution is what Helson would predict, but it is unlikely that he would have forseen the absence of instruction effect upon the higher anchors.

The second possible reason why this study failed to produce directional biasing for the recall condition, is the possibility of the anchor stimuli not being sufficiently different in length from the standard and comparison stimuli. This is unlikely however, since directional biasing occurred with a recognition procedure employing similar movement lengths. Further, directional biasing has been detected using anchor stimuli very close in nature to the comparison stimuli in other MSTM studies (Craft, 1973; Ellis, 1971; Patrick, 1971). Patrick (1971) found significant directional biasing using linear movement lengths and anchor sizes of similar distance to those used in this study. However,

Patrick's methodology was considerably different and involved retention intervals of 25 seconds.

EXPERIMENT 4

The Effect of Anchor Stimuli on Movement Recall

Contrast effects have been reported in both perceptual judgment studies (Christman, 1954; Ellis, 1971, 1972, 1973a; Pratt, 1933; Sherif, Taub, and Hovland, 1958; Turchioe, 1948) and MSTM studies (Laabs, 1971; Levin, Norman, and Dolezal, 1973). Turchioe (1948) and Sherif, Taub and Hovland (1958) report both contrast and assimilation effects in perceptual judgment. Turchioe found a contrast effect under proactive interference conditions and assimilation under retroactive interference, when subjects made estimates of time judgments. Sherif et al found assimilation for anchor weights above and below the level of standard weight, but contrast effects when extremely heavy, or extremely light anchor weights were used. Sherif et al suggest contrast or assimilation is determined by the relative size of the anchor stimulus.

Very few studies report contrast effects in MSTM. Laabs (1971) and Levin, Norman, and Dolezal (1973) report isolated cases of contrast, but the effects of extremely larger or smaller anchor stimuli have not been systematically examined in any MSTM study.

Experiment 4 was established to test if contrast effects are exhibited when anchor stimuli, extremely larger and extremely smaller than the standard stimulus, are presented in context with the standard.

Directional biasing due to anchor stimuli was not in evidence for the recall condition in Experiment 3. The sizes of anchor stimuli utilized in Experiment 3 varied from 5 cm below the standard stimulus of 15 cm, to 10 cm above it. The main reasons postulated for a lack of directional biasing with these movement lengths, were anchor length ineffectiveness, and response strategies used by subjects; thus weakening the anchor effect. The following experiment was established to test both of these hypotheses and, in addition, to test the findings of Sherif et al with a MSTM task.

A recall paradigm involving a number of catch trials was employed in the following experiment in order to eliminate any effects of unjudged stimuli. In addition to the three anchor lengths used in previous experiments (viz. 10 cm, 15 cm, and 20 cm), the effects of very small (3 cm) and very large (60 cm) anchor stimuli were investigated. (Note: the anchor sizes of 3 cm and 60 cm were chosen on the basis of practicality when using a linear hand slide).

The experiment was established to consider the directional biasing effects of five anchor stimuli on the reproduction of a standard stimulus. Catch trials involving recall of the anchor stimuli were included to help eliminate subject response strategies. Instead of disregarding the catch trials, they were considered in the form of the effect *one* standard stimulus had on the reproduction of *five* anchor

stimuli.* In essence, the following experiment considered the effects of five anchor stimuli (3 cm, 10 cm, 15 cm, 20 cm, and 60 cm) on the recall of a 15 cm standard, and the effect of a 15 cm anchor stimulus on the recall of five (3 cm, 10 cm, 15 cm, 20 cm, and 60 cm) standard stimuli.

* The words anchor and standard have been applied by the author. They are, in fact, interchangeable and so it is possible to consider what effect a standard stimulus has on recall accuracy of an anchor stimulus.

Method

Subjects

Five male and four female postgraduate students (aged 23-36 years) voluntarily participated in this experiment. All nine subjects wrote with their right hand.

Apparatus and Task

The apparatus was identical to that described in Experiment 3.

The task was very similar to that reported in Experiment 3. The only change was the omission of the possibility of three movement lengths being presented. Only two movement lengths were presented each trial. The subject was verbally postcued to reproduce one of the two movements.

Design

The main experiment was a factorial design (2X5) in which nine subjects were tested under all levels of both factors, namely, anchor position and anchor size. The two levels of anchor position were presentation of A before K, and K before A. The five levels of anchor size were anchor lengths of 3 cm, 10 cm, 15 cm, 20 cm, and 60 cm. Each subject received five trials for each condition.

The catch trials were set up in a factorial design (2X5) in which nine subjects were tested under all levels of both factors, namely, anchor position and standard size.

The two levels of anchor position were A before K, and K before A. The five levels of standard size were standard lengths of 3 cm, 10 cm, 15 cm, 20 cm and 60 cm. Each subject received five trials for each condition.

The total 100 trials for the main experiment and catch trials were randomly ordered.

Procedure

The procedure was similar to that described in Experiment 3 with two modifications. First, in Experiment 3 subjects initially recalled the standard movement length (15 cm) with interstimulus intervals of 3 seconds and 12 seconds. Twenty trials were given with each interstimulus interval. This occurred, and in addition was repeated for movement lengths of 3 cm, 10 cm, 20 cm, and 60 cm. A total of 200 trials (20 trials X 5 lengths X 2 interstimulus intervals) was administered to each subject.

Secondly, Experiment 3 included both recognition and recall procedures: here, recall only was requested. Subjects received two movement lengths each trial and were always postcued to recall one of them. Recall of either movement was equiprobable.

The experiment took four sessions (held on subsequent days). Due to the large number of initial trials (200) involving interstimulus intervals of 3 seconds and 12 seconds, two sessions were devoted to this task. The main conditions took two sessions; 50 trials per session.

Distribution of the 100 trials is summarized in Table 13.

The five anchors used were 3 cm, 10 cm, 15 cm, 20 cm, and 60 cm lengths, and each of these occurred a total of 20 times (10 each session). The 100 trials were separately randomized.

Data Analysis

The recall data were reduced to CE and VE scores in a similar manner to that described in Experiment 3. The CE data is given in Tables 14 and 15, and the VE data is given in Tables 16 and 17.

Results

Analysis of the main experiment:

The CE and VE data were each submitted to a repeated measures analysis of variance. None of the main effects or interactions were significant for either CE or VE ($p > .05$).

Analysis of catch trial data:

The CE and VE catch trial data were each submitted to a repeated measures analysis of variance. The main effect of standard size was found to be significant for both CE, $F(1,8) = 8.48$, $p < .025$, and VE, $F(1,8) = 10.70$, $p < .025$.

None of the CE interactions involving the order of presentation factor were significant, so the CE data were collapsed over this factor, and each condition

Table 13

Distribution of Trials Among the Four Conditions

No. of Trials	Condition	Task
25	AK	Recall K
25	KA	Recall K
25	AK	Recall A
25	KA	Recall A

Note: K = Standard Stimulus
A = Anchor Stimulus

Table 14

Constant Error (cm) for Recall of Standard (K)

S	ORDER									
	AK					KA				
	ANCHOR SIZE (cm)					ANCHOR SIZE (cm)				
	3	10	15	20	60	3	10	15	20	60
1	-0.63	0.93	-0.73	0.33	0.12	1.59	0.91	0.87	0.48	-0.32
2	1.41	1.31	0.96	0.31	1.76	1.88	-1.48	-0.49	-1.31	0.43
3	0.08	0.20	0.11	0.17	0.03	0.13	0.11	0.28	0.04	0.28
4	0.01	-0.01	-0.16	-0.03	0.20	0.29	-0.50	-0.07	0.19	-0.08
5	0.83	-0.44	1.13	0.92	0.11	1.27	-1.51	-0.12	1.11	1.33
6	-0.44	-1.23	-0.50	-0.40	0.27	-0.51	-0.69	0.31	0.80	0.49
7	0.70	0.44	-0.37	0.98	1.93	0.63	1.25	0.40	2.01	1.70
8	0.24	0.17	0.92	0.25	0.06	2.07	0.35	-0.77	-0.65	-0.23
9	0.69	-0.59	-0.09	-0.21	1.07	0.49	-0.75	-0.43	-0.79	3.49
$\bar{x}$	0.32	0.00	0.14	0.26	0.62	0.87	-0.26	0.00	0.21	0.79

NOTE: K = Standard Stimulus

A = Anchor Stimulus

S = Subject

Table 15

Constant Error (cm) for Recall of Anchor (A)

S	ORDER									
	AK					KA				
	ANCHOR SIZE (cm)					ANCHOR SIZE (cm)				
	3	10	15	20	60	3	10	15	20	60
1	0.07	-1.46	0.48	-0.81	2.24	-0.09	-2.08	0.43	0.08	1.67
2	0.69	2.07	-0.76	-0.39	0.86	0.79	0.89	0.49	0.41	1.59
3	-0.15	0.13	0.07	0.24	0.19	0.47	0.07	0.05	0.12	0.39
4	-0.44	-0.40	-0.09	0.52	1.13	-0.06	0.07	0.07	0.43	1.09
5	-0.29	0.65	-0.48	0.08	0.35	-0.01	0.65	-0.13	-0.57	2.78
6	0.00	-1.07	0.53	0.23	1.44	-0.27	-0.01	-0.19	0.77	-0.16
7	0.24	-0.81	0.83	-0.09	3.13	0.32	0.41	0.43	0.62	3.75
8	-0.29	0.12	-0.53	1.07	5.02	-0.28	-0.36	0.51	-0.99	0.30
9	0.27	-1.35	-0.23	0.16	1.05	0.08	-0.68	-0.01	-0.73	-0.84
$\bar{x}$	0.01	-0.24	-0.09	0.11	1.71	0.11	-0.12	0.18	0.02	1.17

NOTE: K = Standard Stimulus

A = Anchor Stimulus

S = Subject

Table 16

Variable Error for Recall of Standard (K)

S	ORDER									
	AK					KA				
	ANCHOR SIZE (cm)					ANCHOR SIZE (cm)				
	3	10	15	20	60	3	10	15	20	60
1	1.12	1.09	1.62	0.79	2.70	5.30	1.60	2.35	1.06	0.20
2	0.16	0.30	1.83	0.54	2.94	0.54	0.55	3.57	2.12	3.73
3	0.01	0.03	0.03	0.03	0.04	0.08	0.04	0.08	0.02	0.02
4	0.03	0.06	0.04	0.09	0.35	0.05	0.06	0.05	0.13	0.01
5	1.92	0.65	3.61	1.19	4.30	2.86	1.81	0.48	2.66	2.48
6	0.60	1.25	0.28	0.45	2.33	1.07	0.53	1.54	0.89	0.60
7	1.10	0.25	4.43	2.36	1.87	1.69	1.33	4.55	0.38	6.27
8	0.67	0.07	0.38	0.66	2.40	3.36	0.10	0.34	0.18	1.85
9	1.04	1.48	1.82	0.49	1.86	0.26	1.60	1.78	2.97	8.54
$\bar{x}$	0.74	0.65	1.56	0.73	2.09	1.69	0.79	1.64	1.16	2.63

NOTE: K = Standard Stimulus

A = Anchor Stimulus

S = Subject

Table 17

Variable Error for Recall of Anchor (A)

S	ORDER									
	AK					KA				
	ANCHOR SIZE (cm)					ANCHOR SIZE (cm)				
	3	10	15	20	60	3	10	15	20	60
1	0.38	1.10	1.14	1.38	0.82	0.12	1.62	0.80	0.82	6.06
2	0.24	1.08	3.43	1.35	1.96	0.33	0.34	2.80	1.24	3.42
3	0.03	0.55	0.02	0.07	0.11	0.23	0.49	0.21	0.08	0.09
4	0.15	0.27	0.01	0.53	0.22	0.31	0.22	0.02	0.30	0.73
5	0.22	1.21	0.92	0.97	0.47	0.10	0.92	0.15	1.79	1.35
6	0.02	0.88	3.47	0.08	2.67	0.10	1.11	0.24	1.98	4.07
7	0.36	2.03	0.11	1.40	5.94	0.20	1.47	1.86	0.53	4.37
8	0.19	1.80	0.13	0.60	0.91	0.24	1.46	0.87	1.00	6.40
9	0.37	0.68	1.01	0.85	3.62	0.16	1.53	0.12	0.58	3.87
$\bar{x}$	0.22	1.07	1.14	0.80	1.86	0.20	1.02	0.79	0.92	3.37

NOTE: K = Standard Stimulus

A = Anchor Stimulus

S = Subject

further analyzed for anchor effects using Tukey's test on means. This indicated that the 60 cm standard scores differed from those of the 20 cm ($p < .05$), 15 cm ($p < .05$), 10 cm ($p < .01$), and 3 cm ($p < .05$) standards. All other comparisons were nonsignificant. The CE data for both the main experiment and catch trials, collapsed across order of presentation factor, is illustrated in Figure 14.

None of the catch trial VE interactions involving the order of presentation factor were significant, so the VE data were collapsed over this factor. The significant main effect of standard size for VE, $F(1,8) = 10.70$, $p < .025$, was further analyzed using Tukey's test on means. This indicated that recall of the 60 cm standard was significantly more variable than recall of the 3 cm ($p < .05$) standard, but was no more variable at recall than any of the other standards. The VE data for both the main experiment and catch trials, collapsed across order of presentation factor, is illustrated in Figure 15.

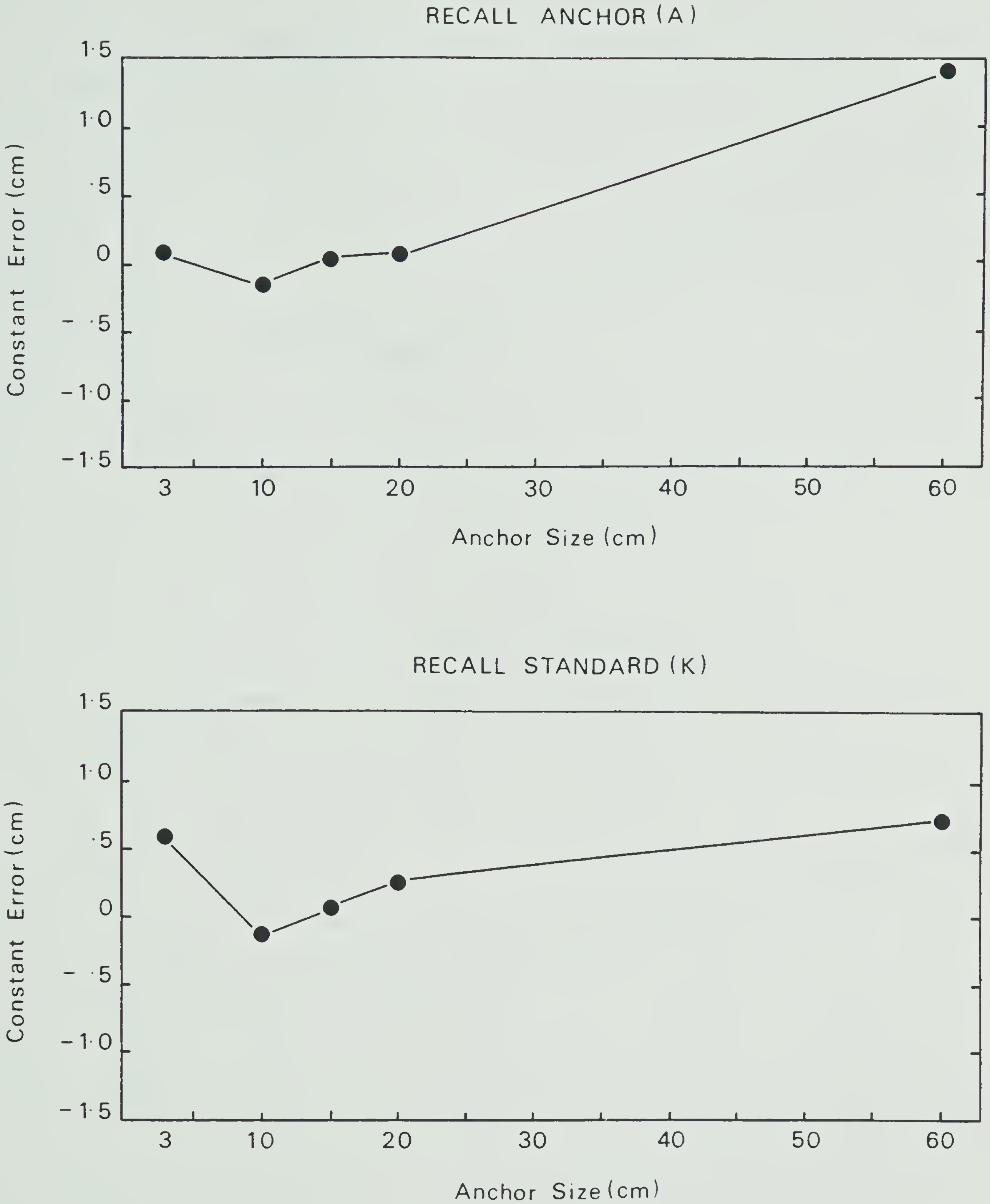


Figure 14. Recall constant error collapsed across order of presentation factor.

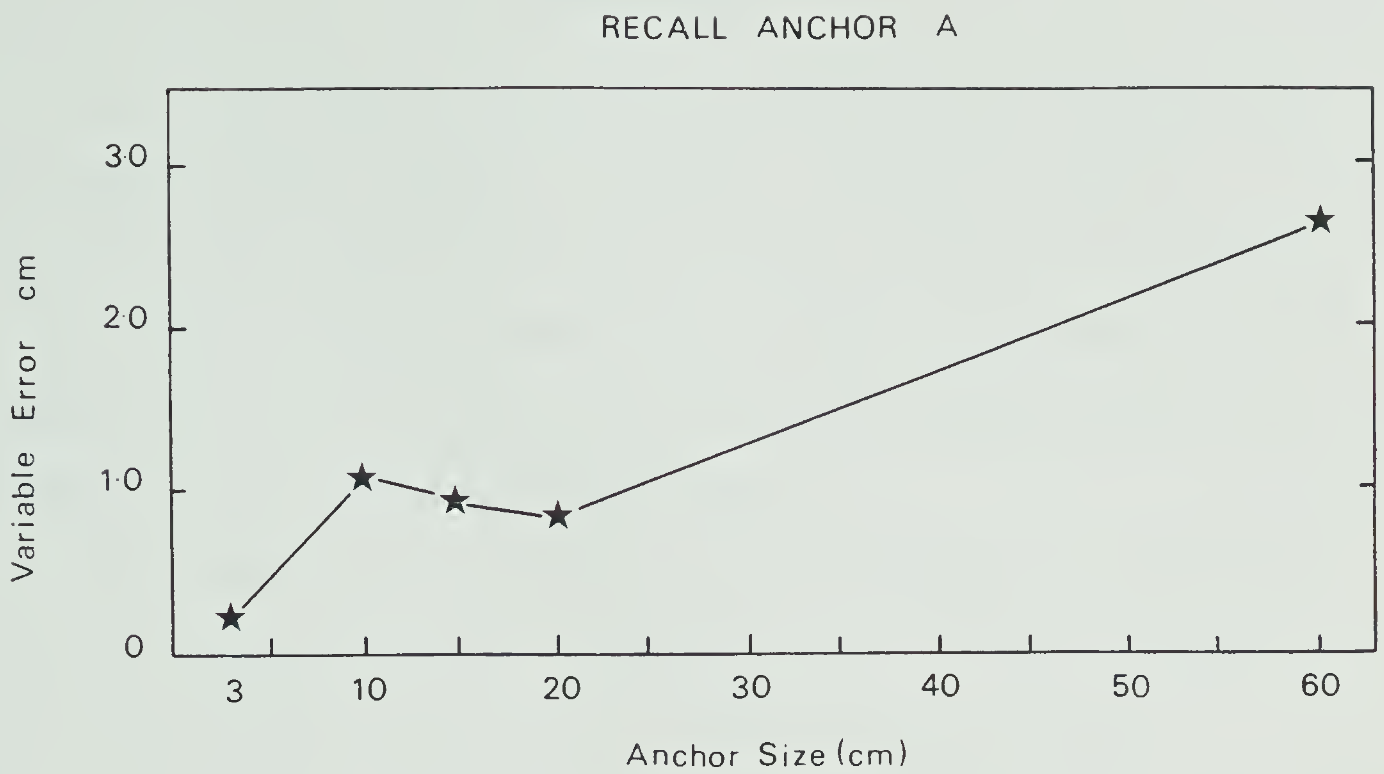


Figure 15. Recall variable error collapsed across order of presentation factor.

Discussion

It can be concluded from the significant shift in CE that directional biasing occurred. Analysis of CE data revealed significant directional biasing for recall of the catch trials. The effect of the five anchor stimuli on recall of the standard 15 cm stimulus was not significant in the main experiment.

The condition where the anchor stimulus is recalled may be considered as the effect a 15 cm anchor stimulus has on the recall fidelity of five standard stimuli. The 15 cm anchor failed to produce any significant directional biasing on standards of 3 cm, 10 cm, 15 cm, and 20 cm, but provided a significant *contrast* effect when presented in context with a 60 cm standard. According to Helson's (1964) adaptation-level theory retroactive assimilation would predict a negative shift in CE toward the smaller anchor stimulus for the condition of small anchor and large standard. Just the opposite (contrast) was true in this study, a significant positive shift in CE occurred. A similar (nonsignificant) contrast effect can be noted in the CE data of the main experiment, illustrated in Figure 14. A positive CE shift occurred for recall of the 15 cm standard presented in context with the small 3 cm anchor stimulus. The 10 cm, 15 cm, 20 cm, and 60 cm anchor stimuli produced the negative slope in CE predicted from retroactive assimilation theory, but the 3 cm anchor produced a sharp

positive rise in CE, thus providing a contrast effect as opposed to assimilation. Although nonsignificant both contrast and assimilation trends are quite clear for the main experiment CE data.

It would appear that perceptual contrast effects do occur with (linear) motor movements, and that two anchor ranges may exist, as proposed by Sherif, Taub, and Hovland (1958) for perceptual judgments. Anchor movements extremely longer and extremely shorter than the standard movement seem to exhibit contrast effects. It should be noted that the methodology of Sherif et al's study has been criticized as one reason for their assimilation and contrast results. Parducci and Marshall (1962), and Parducci, Perrett, and Marsh (1969) criticize Sherif et al's use of a fixed category range for perceptual judgments, and suggest an open range of judgment categories would reduce, if not eliminate, the contrast effects. Ranges of category judgments have not been employed in this study and so such criticisms would be unfounded.

Although a significant assimilation effect was not found in the main experiment, a trend of an assimilation effect is noted across the varying sizes of anchor stimuli (see Figure 14). This is only apparent for recall of the standard of 15 cm with four different anchor stimuli. For the catch trial conditions, an anchor stimulus of 15 cm had very little effect on the recall of 3 cm, 10 cm, 15 cm, and 20 cm standards. A possible reason for the lack of

significant directional biasing effects with all anchor conditions tested, is subject response strategy. Subjects were required to recall both the standard (K) and the five anchor stimuli (A), but due to the nature of the design, 60% of all reproduced movements were 15 cm in length. When a subject was presented with two movement lengths, one length was always 15 cm, and it was a 6:1 chance this length would be asked for on postcued recall. This would no doubt have caused some biasing toward remembering the 15 cm movement.

A significant main effect of standard size was found for catch trial VE data. Recall of the 60 cm standard was significantly more variable than recall of the 3 cm standard stimulus. VE has been indexed as an indicator of the strength of the memory trace (Laabs, 1973, 1979), which suggests the 15 cm anchor stimulus not only caused perceptual contrast but affected the strength of the 60 cm memory trace. A more likely explanation can be offered in terms of Weber's Law, where recall of longer movement lengths would be expected to be more variable than recall of shorter movement lengths. Where length of movement has been included as a variable, differences in retention have been found in distance conditions (Diewert, 1975; Hall & Wilberg, 1978; Kerr, 1978; Laabs, 1977; Roy & Kelso, 1977). The general finding is that VE increases as movements get longer, which agrees with the findings in this study (see Figure 15).

EXPERIMENT 5

Movement Reproduction, Anchor Size, and Response Strategy

The anchor size has been reported as the potent variable when considering anchor effects on motor movements (Craft & Hindrichs, 1971). This may not be the only important variable. The previous experiment produced significant directional biasing (contrast) with an extremely large standard (60 cm) and small anchor (15 cm) but failed to produce significant biasing effects with a small standard (15 cm) and extremely large anchor (60 cm). Indeed, recall of the 15 cm standard movement has not been significantly affected by any anchor movement length varying from -12 cm below this 15 cm standard to +45 cm above it. The anchor size may not be the only variable dictating the directional biasing effects. The size of the standard stimulus may be of equal importance. Laabs (1974) failed to find directional biasing effects with small standard movements for a variety of anchor conditions. He later postulated that small movements may be coded in memory in a different way to larger movements (Laabs, 1978). The following experiment was established to consider the effects of anchor stimuli on a standard movement of larger distance than 15 cm. A movement distance of 40 cm (approximately mid-way along the linear slide bar) was chosen as the standard.

One other possible reason for the lack of directional biasing found in previous experiments is subject response strategy. Not one of the experiments in this series is

without flaw in this respect. The previous experiments did not include 100% catch trials and it is possible that some form of response biasing could have occurred. Indeed, Poulton (1979) suggests, "Avoiding all the biases requires exceedingly rigorous investigations." (p. 777) Many of the MSTM research studies involving anchor stimuli have minimized subject strategies by requiring a reproduction after only one presentation of the set of movements to be remembered. This form of testing prevents knowledge from prior trials being used to set up a subsequent response strategy. Such a procedure was used in the following experiment to minimize response strategies.

Presenting an anchor stimulus before the standard has been shown to produce less directional biasing effects than if presentation occurs following the standard (Craft, 1973; Craft & Hindrich, 1971). This condition was also tested in the following experiment.

Method

Subjects

The subjects were 80 undergraduate physical education students (aged 18-31 years) who participated in this experiment as part of an introductory Human Performance course requirement. All 80 subjects (36 males and 44 females) wrote with their right hand.

Apparatus and Task

The apparatus was the same as that described in Experiment 3 with the following additions. Mounted parallel to the linear slide bar was a standard meter rule. Attached to the cursor was a fine metal pointer which protruded directly above the meter rule. The distance the cursor traversed along the linear slide bar could be monitored to $\pm$ 0.5 mm with the aid of pointer and meter rule readings.

The task was the same as that described in Experiment 4 with one change. The subjects retained their grip on the cursor throughout the trial, thereby reducing the inter-stimulus interval to 3 seconds.

Design

A randomized groups design was employed in this experiment. The 80 subjects were randomly assigned to one of four treatment groups which determined the order of presentation (AK or KA) and size of anchor movement (20 cm or 60 cm). The standard movement (K) was set at 40 cm for all four groups. Each subject received one trial.

Procedure

The procedure was similar to that described in Experiment 4 with the following simplification. Subjects received two movement lengths only (one anchor movement and one standard movement) and were verbally postcued to reproduce the standard movement.

Data Analysis

The dependent variable of CE was calculated for each treatment group and is presented in Table 18.

Results

The CE data were submitted to a one-way analysis of variance. The main effect between groups was found to be significant, $F\ (3,76) = 13.04$, $p<.001$. Each group was further analyzed for treatment effects by the Tukey test. This indicated significant directional biasing effects due to anchor stimuli. The larger 60 cm anchor movement CE shift was significantly different to the shift in CE due to a smaller 20 cm anchor movement ($p<.01$). There was no difference between order of presentation ($p>.05$). Presenting the anchor before the standard produced directional biasing effects to the same degree as presenting the anchor following the standard, for both 20 cm and 60 cm anchors. The mean CE data for all four treatment groups is given in Table 19 and illustrated in Figure 16.

Table 18

Constant Error Data (cm) for Recall of a
40 cm Standard (K)

ORDER							
KA		AK		KA		AK	
ANCHOR SIZE (cm)				ANCHOR SIZE (cm)			
60		60		20		20	
S1	1.9	21	-2.3	41	-1.6	61	-4.2
2	7.0	22	3.0	42	2.8	62	-4.5
3	2.7	23	2.0	43	-3.2	63	-3.3
4	4.0	24	0.2	44	0.5	64	-1.5
5	5.5	25	4.4	45	-6.9	65	-1.6
6	1.7	26	-1.8	46	-0.5	66	-2.5
7	-1.8	27	1.4	47	3.2	67	-2.5
8	-0.8	28	9.0	48	-4.8	68	-4.3
9	0.5	29	2.8	49	-7.0	69	1.5
10	8.4	30	-4.6	50	-5.6	70	-5.4
11	0.2	31	2.2	51	0.0	71	-9.0
12	5.8	32	0.7	52	2.4	72	1.7
13	-4.5	33	-0.8	53	0.0	73	-2.2
14	3.6	34	1.3	54	-2.2	74	-1.6
15	-1.5	35	2.6	55	-3.2	75	-5.1
16	8.0	36	6.5	56	-2.6	76	-3.1
17	1.4	37	0.5	57	-3.2	77	-1.4
18	2.0	38	0.6	58	-6.2	78	2.0
19	1.4	39	1.8	59	3.6	79	-1.2
20	3.7	40	2.3	60	-4.0	80	-2.7
$\bar{x}$	2.5	$\bar{x}$	1.6	$\bar{x}$	-1.9	$\bar{x}$	-2.6

NOTE: K = Standard Stimulus
A = Anchor Stimulus
S = Subject

Table 19

Mean Constant Error Data (cm.) for
all Four Treatment Groups

Treatment Group	K	A	A	K	K	A	A	K
Movement Lengths (cm)	40	60	60	40	40	20	20	40
Mean CE (cm)	+2.5		+1.6		-1.9		-2.6	

NOTE: K = Standard Stimulus

A = Anchor Stimulus

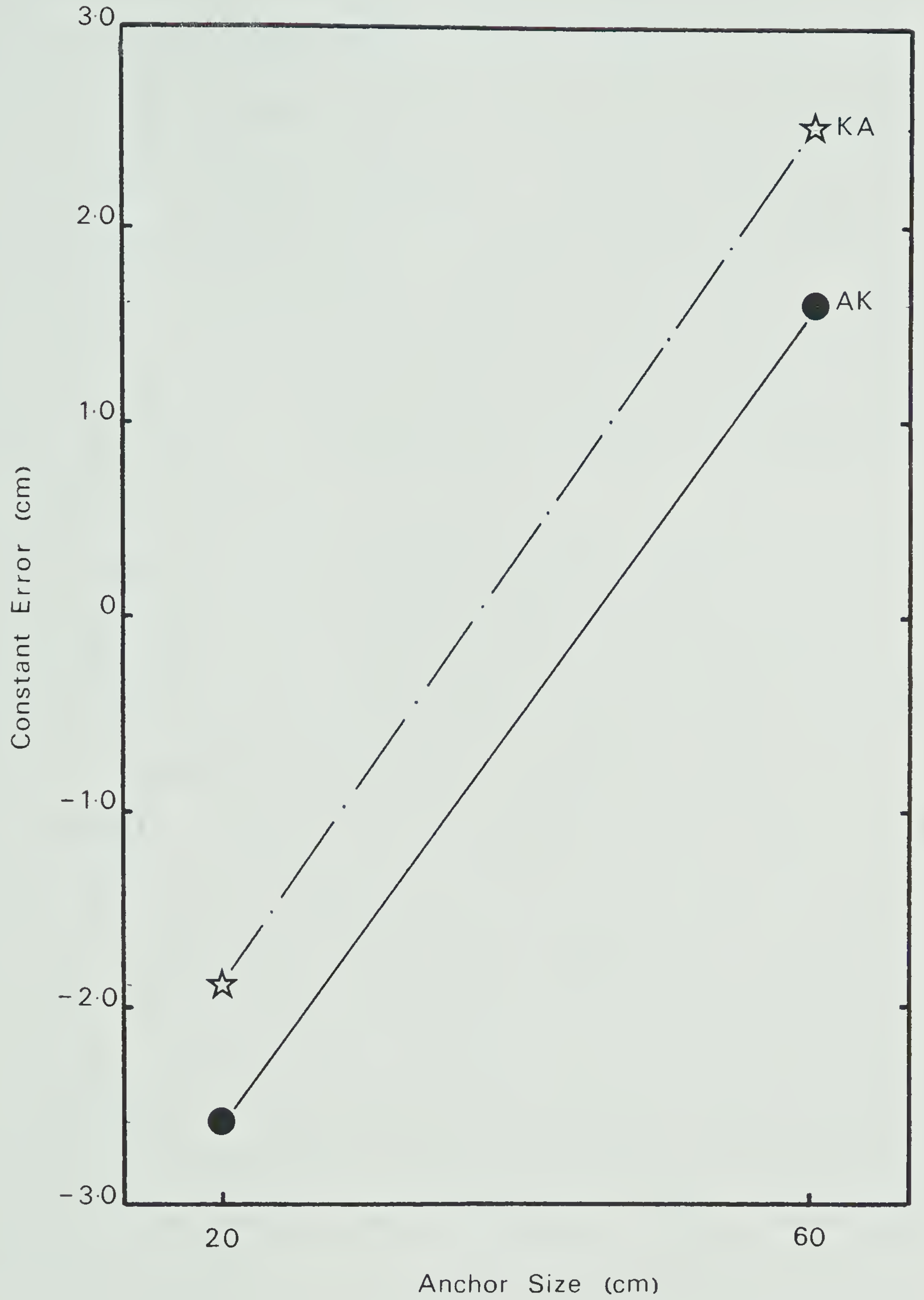


Figure 16. Constant error for recall of a 40 cm standard.

Discussion

Significant retroactive assimilation effects were evidenced in this experiment. The anchor stimuli of 20 cm and 60 cm caused significant shifts in reproduction CE of a 40 cm standard movement. The 20 cm anchor caused a significant negative shift in CE, whereas the 60 cm anchor caused a significant positive shift in CE. The directional biasing effects caused by the anchor stimuli therefore appear to be caused by retroactive assimilation effects (Helson, 1964).

The finding by other MSTM researchers (Craft, 1973; Craft & Hindrichs, 1971) that anchors preceding the standard movement produce a weaker assimilation effect compared to when they follow the standard, was not totally upheld. This was the case for the larger anchor stimulus (60 cm) but presentation of the small anchor (20 cm) in a preceding condition, produced a greater shift in CE than when it followed the standard movement.

A difference in directional biasing for a preceding as opposed to a following anchor stimulus, is predicted from adaptation-level theory (Helson, 1964). Adaptation-level theory predicts a different relation when anchor and standard are reversed. The adaptation-level is a weighted mean of all stimuli, past and present, which affect judgment. The standard stimulus, while exerting predominant influence, is only one of the determinative factors. When the order of presentation of the standard

and anchor is reversed, a new relationship between stimuli and judgment is found (Michels & Helson, 1954).

Only one trial per subject was given in this experiment in an effort to eliminate subject response strategies. Although only one trial data were used in the analysis of this experiment, subjects were asked to perform a second trial with "two *new* movements" before leaving the testing session. It was very evident, even with instructions to the contrary, subjects were consistently seen to 'hunt' for similar distances to those received in the first trial. One trial data would therefore seem to be one method of reducing such response strategies.

EXPERIMENT 6

Movement Reproduction and Effective Anchor Range

The findings from Experiments 4 and 5 provide differential results in terms of long and short standard movements and their corresponding shifts in CE due to the presence of anchor stimuli. It would appear that not all movement distances are affected to the same degree by anchor stimuli. Reproduction of a 40 cm standard movement was significantly affected by the presence of anchor stimuli different in magnitude by ± 20 cm; yet reproduction of a 15 cm standard movement was relatively unaffected by the presence of an anchor movement which was +45 cm greater than the standard. The actual mean shift in CE for the 40 cm standard with a 60 cm anchor was +2.03 cm compared to +0.71 cm for a 15 cm standard with a 60 cm anchor. Both conditions show the positive shifts in CE associated with retroactive assimilation (Helson, 1964), but the smaller standard movement was affected to a lesser degree.

Two reasons may be postulated to account for the differential CE shifts with standards of different lengths. First, a significant contrast effect was found for reproduction of a 60 cm standard movement presented in context with a 15 cm anchor movement in Experiment 4. A similar nonsignificant contrast effect was also noticed for reproduction of a 15 cm standard movement presented

in context with a 3 cm anchor movement in the same experiment. It was concluded from Experiment 4 that extremely large and extremely small anchor movements produce contrast effects as opposed to assimilation effects. Making a comparison between the CE shifts of the 40 cm and 15 cm standards, presented in context with a 60 cm anchor, may not be totally valid. There exists a possibility of both retroactive assimilation and proactive contrast effects working in opposition for the 15 cm standard movement condition. The directional biasing effect of the 60 cm anchor presented in context with the 15 cm standard, may have been the result of both retroactive assimilation *and* proactive contrast, working in opposition. A contrast effect would negate the assimilation effect to some degree. The net result would be a lesser positive shift in CE than would be expected from assimilation effects alone. Had a 35 cm anchor, which is +20 cm longer than the 15 cm standard movement, been presented in context with the 15 cm standard, it might have produced a significant positive shift in CE. This is postulated on the basis that this condition would offer minimal contrast effects as the anchor would not be considered extremely longer than the standard. This idea is speculative and awaits verification.

Researchers in psychophysics and MSTM evoke the principles of assimilation *or* contrast but very few, if any, postulate both contrast *and* assimilation effects

taking place at the same time. Indeed an 'assimilation-contrast' model would account well for the superior assimilation results often obtained when the anchor follows the standard as compared to preceding it. In the following condition (KA), proactive contrast effects of the standard operating on the anchor will always ensure maximum assimilation conditions. The opposite is the case for the preceding condition (AK); proactive contrast effects of the anchor operating on the reception of the standard will negate to some extent the efficiency of the assimilation effect. This holds true for all sizes of anchor and standard movements.

The second possible reason for the lack of a significant shift in CE for the 15 cm standard movement condition, is the likelihood that small movement lengths are relatively unaffected by anchor movement stimuli. This second postulation is the more probable of the two as short distances have been reported in MSTM studies to be unaffected by anchor stimuli (Laabs, 1974; Stelmach & Walsh, 1972, 1973).

Concerning the nature of distance and location cues, Laabs (1977) suggests a location cue is based on "the representation of one or more points in space which are stored in reference to some landmark" (p. 4); while a distance cue is based more on the sense of movement duration. More specifically, Laabs assumes the start and end point of a short movement are stored, and that only the end point of a long movement is stored. Such a

differential coding idea ties in well with Gundry's (1975) findings that there is a tendency or preference to use location cues for shorter movements and distance cues for longer movements. Differences in codability may be one explanation of why short and long movements are affected to different degrees by anchor stimuli.

There is some evidence, based primarily on absolute error, that suggests shorter movements may be rehearsable whereas longer movements are not (Keele & Ells, 1972; Laabs, 1977; Posner & Keele, 1969; Stelmach, 1970; Stelmach & Wilson, 1970). It may be that while short movements are rehearsable but subject to capacity interference, long movements are more prone to structural interference (Kerr, 1975). This explanation would account for the findings of Laabs (1974) who found that an interpolated anchor movement only provided interference for longer distances but not shorter distances or end locations.

Finally, the answer may lie with Laabs (1977) who advances a theory concerning the apparent differences in codability according to length. He asserts that a short but not long distance may be easily recoded as two points in space, and these are sensory encoded similar to end location.

The following experiment was established to examine the differential effects of anchor stimuli on the reproduction of small and long movement lengths. Anchor stimuli ranging in length from very small (5 cm) to very long (75 cm)

were presented in the same context as a small movement (15 cm) and a long movement (40 cm). Only one trial per condition was given to each subject for two reasons: (1) to help eliminate response strategies, and (2) to reduce any central tendency or range effects which are known to occur and increase with large numbers of trials (Hall, 1977). To help further reduce response strategies, an equal number of catch trial conditions were included.

From the results of previous experiments in this series of studies, coupled with the findings of Laabs (1974, 1977), who suggests long movements may be encoded differently to short movements and that long movements may be prone to structural interference effects whereas small movements are not (Laabs, 1980), it would seem likely that the long (40 cm) standard movement would be affected to a greater degree of biasing by the anchor stimuli than would the shorter (15 cm) standard movement. Further, the variety of anchor sizes employed in this study should also provide differential biasing effects. For these reasons a set of *a priori* planned contrasts were constructed. Contrasts were planned to test for directional biasing due to anchor stimuli, and planned to test for differential biasing effects between the 15 cm (small) standard movement and the 40 cm (long) standard movement.

Method

Subjects

Five male and five female undergraduate students (aged 21-24 years) voluntarily participated in this experiment. All ten subjects wrote with their right hand.

Apparatus and Task

The apparatus was identical to that described in Experiment 5.

The task was identical to that described in Experiment 5. Two movement lengths were presented each trial. The subject was verbally postcued to reproduce one of the two movements.

Two minor changes from Experiment 5 were required to accommodate the slightly longer movement length (75 cm) used in this study. First, the interstimulus interval during movement presentation was increased to 4.5 seconds, and second, subjects were seated just to the left of the mid-line of the slide bar. This seating position prevented subjects from having to make a right to left hand slide movement terminating beyond their left shoulder.

Design

A factorial design (2X2X5) was used in this study. Each of the 10 subjects were tested under all levels of the three factors; namely, anchor position, size of standard, and anchor size. The two levels of anchor position were presentation of A before K, and K before A. The two levels

of standard size consisted of a small movement length of 15 cm, and a long movement length of 40 cm. The five levels of anchor size were anchor movement lengths of 5 cm, 25 cm, 35 cm, 55 cm, and 75 cm. Each subject received one trial for each condition plus an equal number of catch trials.

The catch trials were also organized in a factorial design (2X2X5) and considered the directional biasing effects the two standard movements (15 cm and 40 cm) had on reproduction accuracy of the five anchor stimuli. Each of the 10 subjects were tested under all levels of the three factors; namely, anchor position, size of standard,and anchor size. The two levels of anchor position were presentation of A before K, and K before A. The two levels of standard size consisted of a small movement length of 15 cm, and a large movement length of 40 cm. The five levels of anchor size were anchor movement lengths of 5 cm, 25 cm, 35 cm, 55 cm, and 75 cm. Each subject received one trial for each catch trial condition.

Procedure

The procedure was identical to that described in Experiment 5 with one exception. Subjects were presented two movement lengths each trial (A and K) and required to recall one of the two movements. Subjects performed 20 experimental trials (Recall K) plus 20 catch trials (Recall A). All 40 trials were randomly ordered. Distribution of the 40 trials is summarized in Table 20.

Table 20

Distribution of Trials Among the Four Conditions

No. of Trials	Condition	Task
10	KA	Recall K
10	AK	Recall K
10	KA	Recall A
10	AK	Recall A

NOTE: K = Standard Stimulus

A = Anchor Stimulus

Data Analysis

Constant error (CE) was calculated from the reproduction data. The CE data for reproduction of the standard movement lengths of 15 cm and 40 cm are presented in Tables 21 and 22 respectively. The CE data for reproduction of the anchor stimuli presented in context with standard movement lengths of 15 cm and 40 cm are given in Tables 23 and 24 respectively.

Results

The CE data for recall of the standard movement lengths of 15 cm and 40 cm, were submitted to a repeated measures analysis of variance: 2 (standard size) X 5 (anchor size) X 2 (anchor position). The main effect of standard size was found to be significant, $F\ (1,9) = 75.65$, $p<.001$. The main effect of anchor size was also significant, $F\ (1,9) = 7.65$, $p<.025$.

None of the interactions involving anchor position factor were significant, so the CE data were collapsed over this factor, and each condition further analyzed using the planned contrasts. Contrasts were conducted on the significant main effects of standard size and anchor size. The mean CE, collapsed across order of anchor presentation factor, for recall of the standard movement lengths of 15 cm and 40 cm, is illustrated in Figure 17.

The results of the planned contrast tests made on the standard size main effect were that the five anchor stimuli produced significantly different biasing effects on recall

Table 21

Constant Error Data (cm) for Recall of the Standard Movement of 15 cm

S	ORDER									
	KA					AK				
	ANCHOR SIZE (cm)					ANCHOR SIZE (cm)				
	5	25	35	55	75	5	25	35	55	75
1	-0.5	0.2	-0.8	0.5	1.7	-0.7	-1.4	1.0	2.6	-1.6
2	2.2	1.0	4.8	2.9	1.1	-0.2	1.1	3.4	0.8	0.5
3	1.4	-2.6	1.6	1.1	1.1	4.0	1.1	1.2	3.8	1.7
4	2.0	1.6	2.0	4.2	2.6	0.4	2.7	3.3	1.5	1.1
5	0.4	4.1	3.3	2.5	5.6	3.2	-0.2	1.6	1.5	-0.4
6	4.2	1.4	0.2	2.2	-0.9	-0.6	-0.5	0.4	0.3	-0.7
7	-1.8	-2.3	0.1	-0.6	1.4	0.2	1.3	-0.5	2.4	-2.3
8	-2.0	0.7	3.7	-0.6	3.0	3.5	3.6	1.2	-0.3	2.8
9	1.8	0.8	2.0	-1.2	-2.0	-0.5	-0.5	0.7	4.2	2.7
10	-0.2	1.8	-0.4	2.9	-1.2	1.6	2.3	-2.0	3.9	-0.9
$\bar{x}$	0.75	0.67	1.65	1.39	1.24	1.09	0.95	1.03	2.07	0.29

NOTE: K = Standard Stimulus

A = Anchor Stimulus

Table 22

Constant Error Data (cm) for Recall of the Standard Movement of 40 cm

S	ORDER									
	KA					AK				
	ANCHOR SIZE (cm)					ANCHOR SIZE (cm)				
	5	25	35	55	75	5	25	35	55	75
1	-1.9	-0.2	-1.2	1.8	-4.2	-1.5	-3.7	0.9	3.8	-3.8
2	1.9	-0.3	-3.1	2.6	-0.3	1.5	-0.4	1.1	1.7	-4.6
3	0.2	-0.4	0.6	0.3	-1.8	-0.9	-2.6	-3.0	0.3	-0.4
4	-7.2	-1.0	1.7	1.0	-7.6	-3.8	-1.4	3.3	-0.4	-2.9
5	-1.8	2.9	-1.3	2.9	6.4	-4.3	-2.3	-0.4	4.4	-4.1
6	2.3	-5.5	-3.1	-4.7	-8.0	-3.1	-0.4	-4.0	0.7	-4.7
7	0.0	-3.7	-4.0	0.0	-3.9	-2.7	-3.9	-3.8	0.8	-4.2
8	3.9	-3.7	0.0	1.3	-2.1	-0.9	-3.6	-1.5	1.5	-0.8
9	-3.1	-4.8	-0.3	0.2	-2.5	-5.8	-4.0	-0.1	-2.3	-3.8
10	-5.9	-3.3	1.3	0.7	-5.4	-1.2	-3.3	0.3	-1.6	-5.1
$\bar{x}$	-1.16	-2.00	-0.94	0.61	-2.94	-2.27	-2.56	-0.72	0.89	-3.44

NOTE: K = Standard Stimulus

A = Anchor Stimulus

Table 23

Constant Error Data (cm) for Recall of the Anchor Stimuli with a Standard Movement of 15 cm

S	ORDER									
	KA					AK				
	ANCHOR SIZE (cm)					ANCHOR SIZE (cm)				
	5	25	35	55	75	5	25	35	55	75
1	3.3	-4.2	-3.1	-3.5	0.5	0.0	-2.6	-3.3	0.3	1.4
2	0.0	-0.4	-1.5	1.0	6.4	2.8	0.2	-1.5	0.3	0.9
3	-1.0	-0.8	-0.6	3.7	0.8	-0.7	3.2	-2.2	6.4	-2.4
4	2.0	-2.4	-0.6	3.8	-0.5	4.0	0.4	0.0	4.8	1.2
5	1.2	-2.3	-0.9	1.1	1.0	4.4	0.4	-1.0	0.5	5.7
6	1.9	-2.1	-3.4	-1.4	1.1	-0.6	-0.8	0.1	-1.2	0.8
7	0.5	-2.3	-3.5	1.3	-1.1	1.3	-0.3	-5.1	-0.4	-0.1
8	2.4	-0.5	-3.1	5.3	-0.2	1.9	-0.5	5.1	4.0	1.0
9	1.6	-0.6	-4.3	-3.8	1.6	-0.5	1.1	-0.5	-6.5	0.9
10	0.4	-1.4	0.0	-2.0	2.4	0.0	1.2	-4.8	-2.3	-0.5
$\bar{x}$	1.23	-1.70	-2.10	0.55	1.20	1.26	0.23	-1.32	0.49	0.89

NOTE: K = Standard Stimulus

A = Anchor Stimulus

Table 24

Constant Error Data (cm) for Recall of the Anchor Stimuli with a Standard Movement of 40 cm

S	ORDER									
	KA					AK				
	ANCHOR SIZE (cm)					ANCHOR SIZE (cm)				
	5	25	35	55	75	5	25	35	55	75
1	2.3	0.2	-2.6	-1.9	-1.7	-0.5	-4.5	4.0	-3.8	-7.2
2	-0.4	1.1	3.5	-4.2	6.0	-0.5	1.2	-2.8	0.4	2.8
3	1.8	2.8	2.3	-0.6	3.8	3.4	1.6	0.8	0.3	-0.1
4	1.5	-3.8	3.3	0.5	0.5	1.9	-2.8	3.2	1.1	-1.9
5	1.5	-0.5	2.8	-1.1	4.2	4.2	5.0	6.3	-1.1	4.2
6	-0.6	-0.2	0.0	-1.5	0.1	1.2	-0.5	1.4	0.0	-5.9
7	3.2	-0.2	-0.6	-1.5	-2.5	-2.8	2.3	-0.9	-6.9	-2.7
8	0.6	0.2	4.1	2.9	-1.9	-1.1	-2.2	-0.5	1.9	2.8
9	3.3	-0.7	3.8	0.0	-0.5	2.2	6.4	-1.0	-5.5	0.6
10	1.0	0.8	-0.3	-4.6	-2.5	-0.1	0.0	1.7	-4.8	-8.7
$\bar{x}$	1.42	-0.03	1.63	-1.20	0.55	0.79	0.65	1.22	-1.84	-1.61

NOTE: K = Standard Stimulus

A = Anchor Stimulus

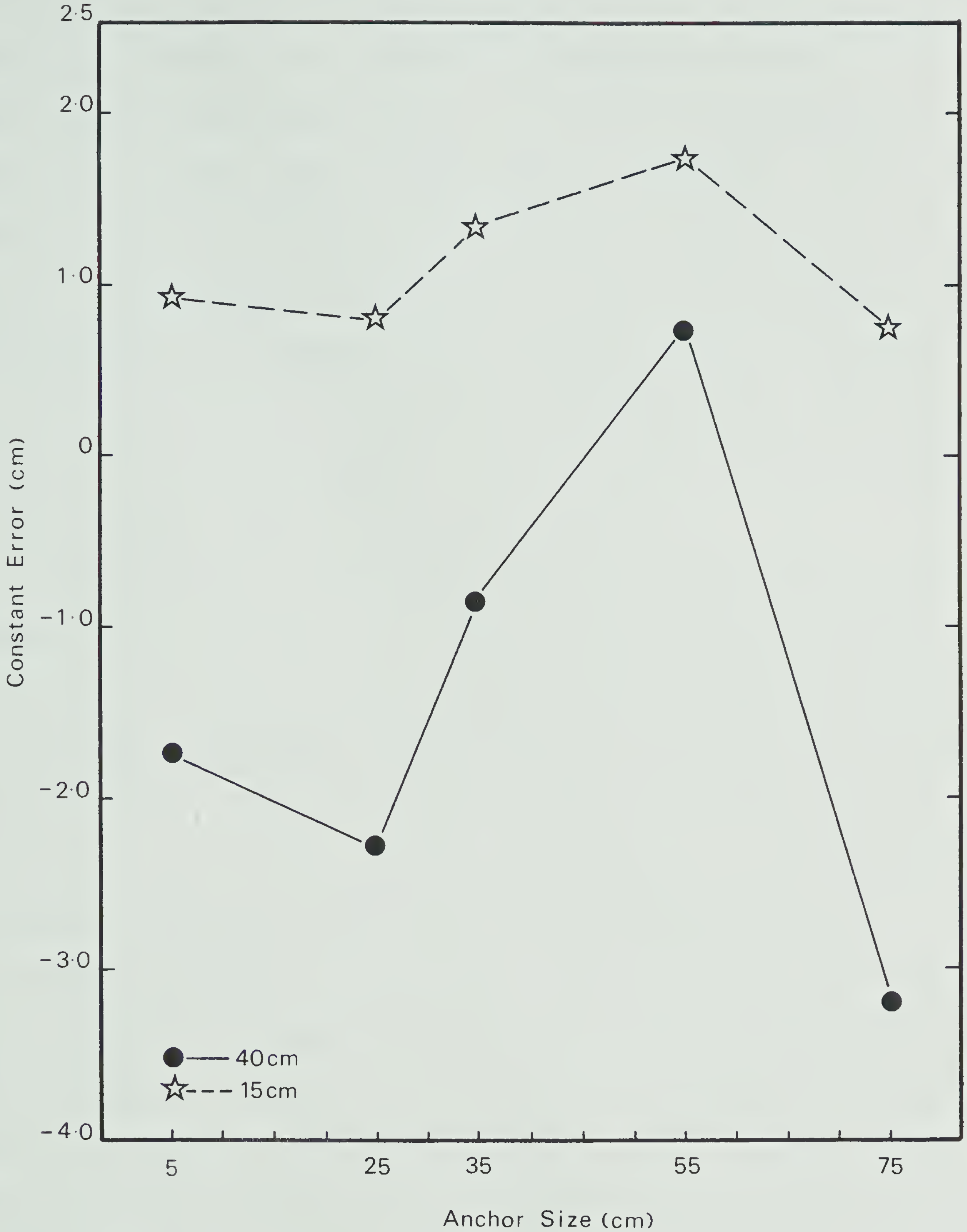


Figure 17. Constant error (collapsed across order of presentation factor) for recall of the standard movement lengths of 15 cm and 40 cm.

of the 40 cm standard compared to recall of the 15 cm standard. Recall CE of the 40 cm standard differed significantly from the recall CE of the 15 cm standard, under four of the five anchor stimuli conditions. Only the 55 cm anchor biasing effects did not significantly differ. The degree to which four of the anchor stimuli significantly differed in their biasing effects on recall of the 15 cm and 40 cm standard movement lengths, were as follows: 5 cm anchor ($\underline{p}<.025$), 25 cm anchor ($\underline{p}<.01$), 35 cm anchor ($\underline{p}<.05$), and 75 cm anchor ($p<.01$).

The results of the planned contrast tests made on the anchor size main effect were that significantly different directional biasing effects occurred in recall CE for the 40 cm standard movement length but not for the 15 cm standard recall length. The five anchor stimuli failed to produce significant directional biasing on recall CE of the 15 cm standard. The same five anchor stimuli provided the following significant directional biasing effects on recall CE of the 40 cm standard movement: the 75 cm anchor produced significantly different biasing effects compared to the 35 cm anchor ($\underline{p}<.05$) and the 55 cm anchor ($\underline{p}<.01$); and the 55 cm anchor biasing effects differed significantly from the 25 cm ($\underline{p}<.025$) and 5 cm ($\underline{p}<.05$) anchor effects (see Figure 17). All other comparisons were nonsignificant.

Catch Trials

The CE data for recall of the five anchor stimuli, when each was presented in context with a standard movement length

of 15 cm or 40 cm, were submitted to a repeated measures analysis of variance: 2 (anchor position) X 2 (standard size) X 5 (anchor size). None of the main effects were found to be significant. However, two significant interactions were in evidence: a significant standard size X anchor size interaction, $F\ (1,9) = 11.4$, $p<.01$, and a significant order of anchor presentation X standard size interaction, $F\ (1,9) = 12.23$, $p<.01$. All other interactions were nonsignificant.

The mean CE (collapsed across order of anchor presentation factor) for recall of the five anchor stimuli when each was presented in context with a standard movement length of 15 cm or 40 cm, is illustrated in Figure 18. The significant interaction between standard size and anchor size can be seen in Figure 18.

The significant interaction between order of anchor presentation and standard size is illustrated in Figure 19.

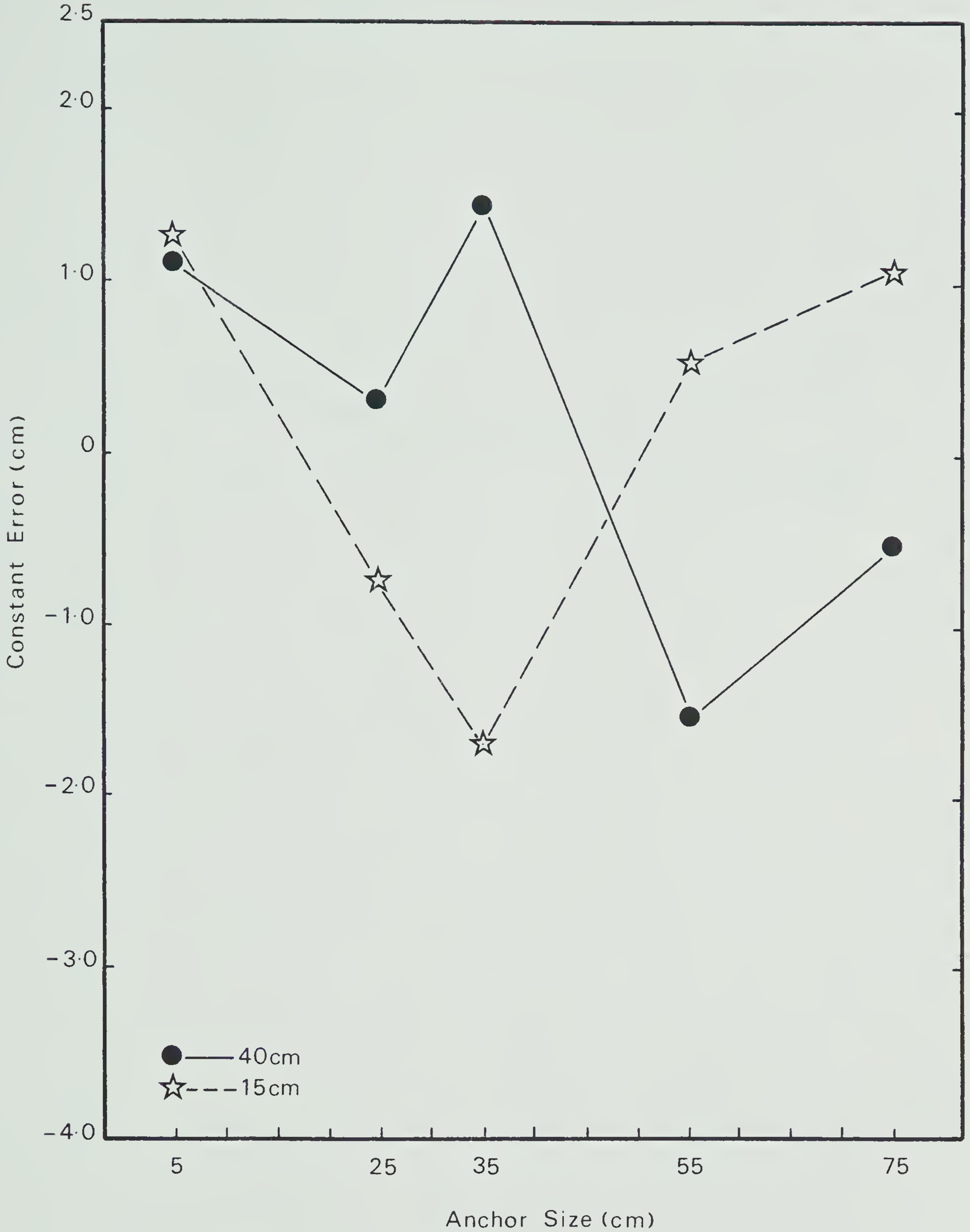


Figure 18. Constant error (collapsed across order of presentation factor) for recall of the five anchor movement lengths when presented in context with standard movement lengths of 15 cm and 40 cm.

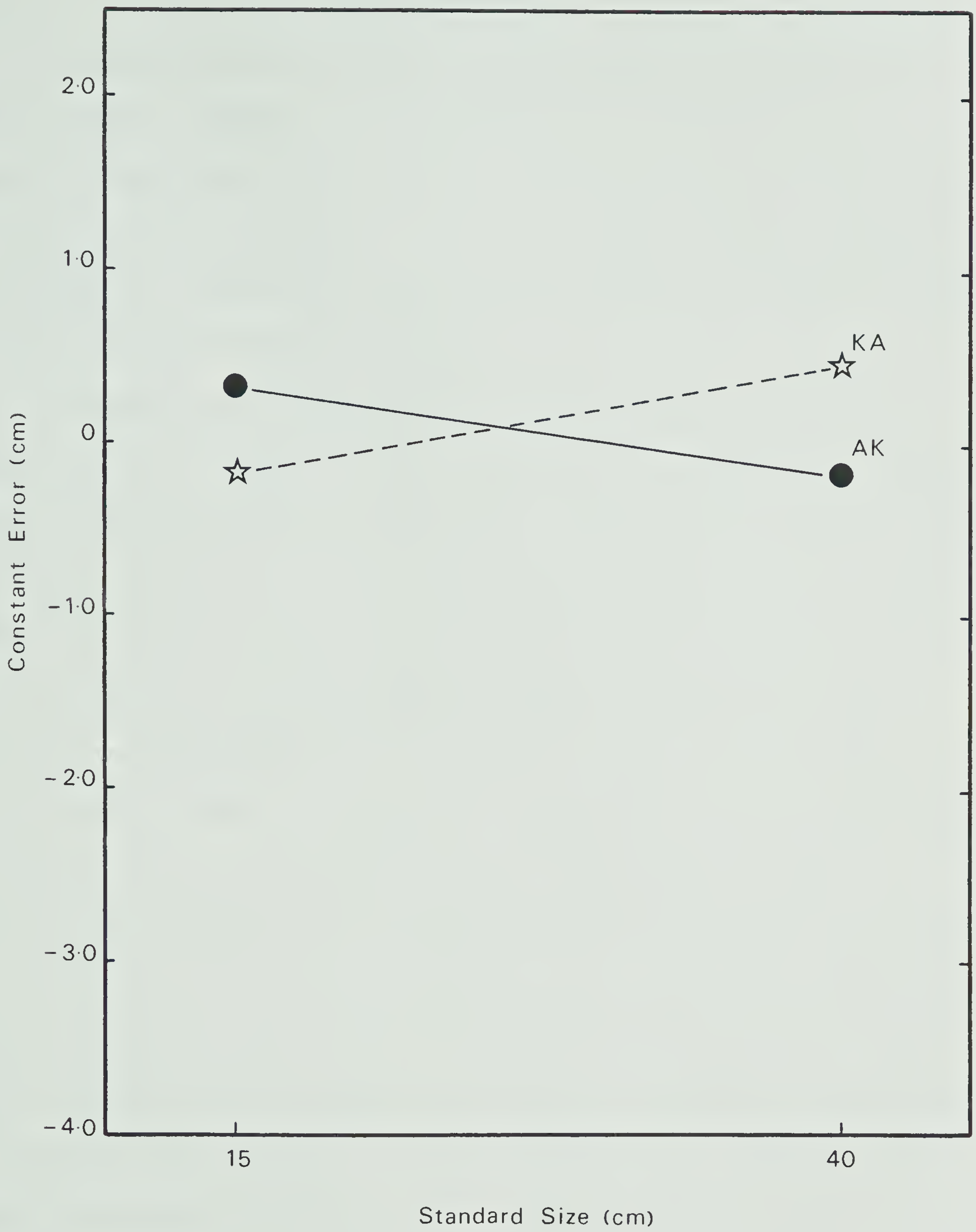


Figure 19. Recall constant error interaction between order of presentation and size of standard (collapsed across anchor size).

Discussion

Significant directional biasing was in evidence in this study. Results of the analysis on CE were that significant directional biasing occurred in recall of the 40 cm standard movement. The five anchor stimuli failed to produce significant directional biasing in recall of the 15 cm standard movement length.

Although the directional biasing effects were non-significant in recall of the small 15 cm standard movement, this statement must be qualified. There is no baseline data for this condition; four of the anchor stimuli were longer than the 15 cm standard and thus produced positive shifts in recall CE. The very small anchor (5 cm) should have produced a negative shift in CE according to retroactive assimilation theory, but due to a proactive contrast effect produced a positive shift in CE. The overall result for recall of the small 15 cm standard was five positive shifts in CE for all five anchor conditions. These five positive shifts in CE did not significantly differ from each other; had a 15 cm control anchor (A=K) been included to provide a baseline data point, a significant shift in CE may have been recorded (see Figure 17). The 15 cm standard recall biasing effects due to the five anchor stimuli, followed the same general pattern as the 40 cm standard recall biasing effects, but to a lesser degree.

Two facts are noteworthy for the directional biasing found in this study. First, considering the CE shifts

associated with recall of the 40 cm standard movement. Significant directional biasing occurred over the middle three anchor lengths, i.e. 25 cm, 35 cm, and 55 cm. The negative and positive shifts in recall CE for the 25 cm, 35 cm, and 55 cm anchor conditions, conform to a *retroactive assimilation* prediction and virtually replicate the findings of Experiment 5. The extremely longer (75 cm) and shorter (5 cm) anchor stimuli produced *proactive contrast* effects. The extremely long 75 cm anchor caused a significant shift in recall CE; moving from a positive shift in CE of 0.75 cm with a 55 cm anchor, to a negative shift in CE of -3.19 cm with the 75 cm anchor. The extremely small 5 cm anchor condition provided the second point of interest. Here a negative shift in CE was observed in recall of the 40 cm standard movement, which conforms to an assimilation viewpoint. However, the negative shift in CE with a 5 cm anchor was *less* than the negative CE shift associated with the 25 cm anchor condition. Interpretation of such a result is that both assimilation *and* contrast effects were in evidence for the extremely small 5 cm anchor condition (see Figure 17). This assimilation and contrast interpretation is further supported by consideration of the CE shifts in recall of the 15 cm standard movement. The 25 cm, 35 cm, and 55 cm anchors all provided positive shifts in CE that increased as the anchor length increased. Retroactive assimilation predicts these positive shifts in CE for the 25 cm, 35 cm, and 55 cm anchor conditions. Similarly the 75 cm anchor produced a

positive shift in CE but was no more positive than the CE shift caused by the much smaller 25 cm anchor. Again it would appear that both a retroactive assimilation *and* a proactive contrast effect were combining to reduce the positive shift in CE for the 75 cm anchor condition. A true proactive contrast effect would be a negative CE shift for recall of a 15 cm standard when presented in context with a 75 cm anchor stimulus. Instead, a depressed positive shift in CE was noted, indicating that a proactive contrast effect had supressed the retroactive assimilation effect to some degree.

The significant differential biasing effect of the same five anchors on the short 15 cm standard and the long 40 cm standard, add further support to the contention that small movements and long movements are encoded differently. Several MSTM researchers have reported that movement size affects retention characteristics (Duffy, Montague, Laabs, & Hillix, 1975; Laabs, 1974, 1977, 1980; Posner & Keele, 1969; Stelmach & Wilson, 1970). Laabs (1974) reported that an interpolated movement only provided interference for longer distances but not shorter distances or end locations. In the present study the five anchor stimuli were able to bias recall accuracy of the 40 cm standard to a greater degree than they were able to bias recall of the 15 cm standard. Proactive contrast effects were also more predominant in the 40 cm standard recall condition. A small movement length of 15 cm appears to be coded quite

efficiently in memory and is not subject to interference effects from anchor movements to the same degree that a longer 40 cm movement is affected. The finding wherein long and short movements were not equally affected by anchor interference effects, lends support to Laabs' (1977, 1980) theory of differential encoding according to movement length.

The catch trial data supported the findings in the main experiment. Although no main effects were significant, the shifts in CE due to the various anchor stimuli were not only evident but followed assimilation/contrast prediction (see Figure 18). Considering first, recall of the five anchor stimuli when each was presented in context with the 15 cm standard movement. The CE shifts associated with reproduction accuracy of the 5 cm, 25 cm, and 35 cm anchor movements conform to a retroactive assimilation prediction. Recall of the 55 cm anchor produced a positive shift in CE which conforms to a proactive contrast prediction. The condition wherein a 15 cm standard was presented in context with a 55 cm anchor conforms to the similar condition tested in Experiment 4 where a 15 cm standard and 60 cm anchor were presented in the same context. Similar results were obtained in that both elicited contrast effects. The extremely long anchor of 75 cm also produced a positive shift in CE which may be considered a proactive contrast effect.

Recall of the five anchor stimuli, when each was

presented in context with the 40 cm standard, provided similar assimilation/contrast results. The positive and negative CE shifts in recall of the 35 cm and 55 cm anchor stimuli respectively, conform to an assimilation prediction. The 75 cm anchor reproduction shift in CE was also negative but to a lesser degree than the 55 cm anchor CE shift. Interpretation of the 75 cm anchor recall shift in CE is that both retroactive assimilation *and* proactive contrast effects were in evidence for this condition, with retroactive assimilation effects dominating. Recall of the 25 cm anchor did not completely conform to the expected prediction. A positive shift in CE would be expected from assimilation theory. This occurred, but was very close to zero in nature, and a full 1.12 cm below the positive CE shift associated with the 35 cm anchor recall. It is unlikely that a contrast effect was occurring in the 25 cm anchor condition as this distance is only 15 cm smaller than the standard length of 40 cm. One tentative explanation is that the 25 cm anchor could be considered a fairly small movement length and so may be fairly resilient to anchor movement interference effects. Support for this explanation is not found with the biasing effects associated with the 5 cm anchor movement. A larger positive shift in CE was found in recall of the 5 cm anchor than in recall of the 25 cm anchor, hence small movements can be subject to interference effects. However, the reproduction of extremely small movement lengths deserves a word of caution. Conforming to Hollingworth's

(1909, 1910) central tendency effect, there is a tendency to overestimate short distances and underestimate long distances. The long distances employed in the present series of studies have been both underestimated *and* overestimated. The extremely short distances, however, have been consistently overestimated in all conditions tested. Indeed, the condition where an extremely small movement length (5 cm) is presented in context with a long (40 cm) movement length presents a condition where proactive contrast would be expected. A negative shift in CE is the expected outcome on the basis of proactive contrast for recall of an extremely small 5 cm movement when presented in context with a long 40 cm movement. Just the opposite was found; reproduction of the 5 cm movement length was consistently overestimated. The tendency to overestimate small movements may contaminate anchor effects and consideration must be given to such conditions.

The significant interaction found between standard size and anchor size is to be expected due to the choice of anchor and standard sizes chosen for this study. The small 15 cm standard movement when presented in context with the long 55 cm and extremely long 75 cm anchor movements, provided a contrast effect and caused positive shifts in anchor recall CE. Conversely, the long 40 cm standard movement when presented in context with the long 55 cm and extremely long 75 cm anchor movements, produced an assimilation effect and thus caused negative shifts in

anchor recall CE (see Figure 18).

The significant interaction found between order of anchor presentation and standard size is a little more difficult to explain. The significant interaction effect is illustrated in Figure 19. The tendency to over and underestimate anchor movement lengths was contingent upon the anchor position and standard size. The interaction effect is reflected in the anchor recall CE data in Tables 23 and 24. Earlier it was reported that recall of the 25 cm anchor, when presented in context with a 15 cm standard, did not completely conform to the predicted directional biasing. The 25 cm anchor condition also included an order of presentation effect. Negative or positive shifts in recall CE were, in general, contingent on whether the anchor preceded (AK) or followed (KA) the standard movement lengths. A similar order of presentation effect occurred in recall CE shifts for the 75 cm anchor when presented in context with the 40 cm standard movement. Differential biasing effects due to order of anchor presentation would contribute to an interaction effect.

Recall of the 75 cm anchor when presented in context with the 40 cm standard, resulted in both a negative (-1.61 cm) and a positive (0.55 cm) shift in CE dependent upon order of anchor presentation. The differential biasing associated with recall of the extremely long anchor stimulus may be an artifact of one trial data and a small sample size, or it may reflect a competition for dominance between

proactive contrast and retroactive assimilation effects. If this were the case, order of anchor presentation may be an important consideration when the anchor and standard movements are considerably different in length.

EXPERIMENT 7

Movement Amplitude, Anchor Effects and Recognition

At the outset of this series of experiments one of the primary objectives was to test the efficacy of a recognition paradigm in a context effect MSTM study. The KAK recognition paradigm was employed with a standard movement of 15 cm and anchor movements of 10 cm, 20 cm, and 25 cm in length. Very few significant results were obtained which eventually prompted a move to a recall paradigm. Again nonsignificant directional biasing effects were found when using the 15 cm standard in movement reproduction.

There is a likelihood that small distances may be treated differently (coded) to long distances (Laabs, 1977, 1980). Further, there is evidence suggesting that small movements may be more rehearsable, and so become less affected by structural interference (Keele & Ells, 1972; Posner & Keele, 1969; Stelmach, 1970; Stelmach & Wilson, 1970). Such factors as coding and rehearsability seem to provide small movement distances with a resistance against the effects of anchor stimuli.

The use of the short 15 cm standard movement, coupled with those response biasing effects due to unjudged stimuli (Poulton, 1979), may have been responsible for the non-significant directional biasing effects found when the KAK recognition paradigm was employed in the previous experiments.

Recognition paradigms have apparently been employed in very few MSTM studies (Hall, 1977; Kantowitz, 1974; Laabs, 1978; Marshall, 1972). The results from such MSTM recognition studies form very little unanimity. Marshall (1972) reported detrimental effects of delay on the recognition of kinesthetic information, but Kantowitz (1974) failed to support this conclusion. Recognition performance was found to be substantially poorer for a long distance compared to a short distance in Hall's (1977) study. However, Kantowitz (1974) reported just the opposite and concluded that superior recognition occurs for greater movement lengths. Hall (1977) further stated there was a higher probability of giving a *less than* judgment than a *greather than* judgment for a short criterion distance when a judgment of *equal to* was infact correct. The reverse was found for the longer distances in the movement range employed by Hall. In those instances there was a higher probability of giving a *greater than* judgment than a *less than* judgment when a judgment of *equal to* was infact correct. In Experiments 1 and 2 where the anchor, standard, and comparison stimuli were each 15 cm in length, the mean proportion of judgments K2<K1 were, on average, 0.42 and 0.45 respectively, when a judgment of *equal to* (0.50) would have been correct. This finding is the exact reverse of Hall's results for short movements, and indicates that there is a tendency to judge the comparison stimulus as being *greater than* the

standard stimulus when infact a judgment of *equal to* would be correct.

The discrepancy noted may very well be due to the inclusion of a third stimulus (anchor) being presented in Experiments 1 and 2 (Hall included only standard and comparison stimuli in his study). This is borne out to some degree by the results of the time-error study in Experiment 1. When two equal movement lengths were presented, the average K2<K1 judgments were 0.49. The proportion of judgments 0.49 is very close to chance (0.50), which would be expected for equal movement lengths, and so the judgmental biases suggested by Hall (1977) are not supported for the 15 cm movements.

The discrepancies reported between the various MSTM recognition studies could be attributed to differences in experimental procedures and the subjects' responses required. Consequently comparisons between MSTM recognition studies may be invalid. Apart from differences in response requirements, the movement distances employed in the various studies were different. Indeed, there is complete variation in MSTM literature as to what constitutes a 'small' and 'long' movement. Hall (1977) considered 5 cm as small and 25 cm as long, whereas Kantowitz's small movement was 16 cm. If it is assumed that there are differences in the encoding and retention characteristics along the dimension of movement length (Laabs, 1977, 1980), then comparison between studies utilizing different movement distances

cannot be legitimately made.

Laabs (1977, 1980) asserted that small movement lengths might be encoded differently to long movement lengths. Short movements may be recoded as two points in space and encoded in a sensory store. Long movements, on the other hand, are assumed to be remembered more on the attribute of distance which would involve movement duration. Further, it is possible short movements may be rehearsed (Keele & Ells, 1972; Posner & Keele, 1969; Stelmach, 1970; Stelmach & Wilson, 1970) and so become fairly resistant to structural interference from anchor movements. Longer movements however, may not be rehearsable and so will be prone to structural interference from anchor movements (Laabs, 1974, 1980). The following experiment was established to test for directional biasing from anchor movements when a long movement length was employed as standard and comparison in the KAK recognition paradigm. Significant directional biasing effects were found in Experiment 5 for reproduction of a standard movement of 40 cm when presented in context with anchor movements of 20 cm and 60 cm. Similar distances were employed in the following KAK recognition experiment because of their known directional biasing effects.

Significant directional biasing in reproduction accuracy was found in Experiment 5 with standard and anchor lengths of similar distance to those employed in this study. The long (60 cm) and short (20 cm) anchor movements

caused significant shifts in the recall CE of a 40 cm standard movement. Both anchor lengths provided directional biasing effects appropriate to a retroactive assimilation interpretation (Helson, 1964). Further, it was shown in Experiments 1 and 2 that the respective position of the anchor in a KAK recognition paradigm brought about differential biasing effects in recognition judgment. Significant directional biasing due to the anchor movements and differential biasing effects dependent upon anchor position, may therefore be anticipated in the following study. Consequently, a set of a priori planned comparisons were constructed as a test for these expected directional biasing effects.

Method

Subjects

Five male and five female subjects (aged 24-31 years) voluntarily participated in this experiment. The ten subjects were graduate students who wrote with their right hand.

Apparatus and Task

The apparatus was identical to that described in Experiment 5. A linear slide bar and cursor served to provide movement distances. Interval timers provided control of movement duration and interstimulus interval.

The task was similar to that reported in Experiments 1 and 2. Three movement lengths were presented (K1, A, and K2) each trial. The subject was postcued to make a recognition judgment between K1 and K2, on the basis of length. Both the stimulus duration and interstimulus interval were set at 4.5 seconds. (Note: subjects retained hold of the cursor throughout the experiment).

Design

The experiment was a factorial design (3X3) in which all ten subjects were tested under all levels of both factors, namely: anchor position and anchor size. The three levels of anchor position were a preceding anchor (AKK), an interpolated anchor (KAK), and a following anchor (KKA). The three levels of anchor size were anchor movement lengths of 20 cm, 40 cm, and 60 cm.

Procedure

The procedure was very similar to that described in Experiments 1 and 2. Subjects received three movement lengths of which two were compared on the dimension of length. The only changes from Experiments 1 and 2 were in the postcuing and response procedures. The subject was verbally postcued to make a recognition judgment between two of the three movements, on the basis of length. A verbal response, indicating which of the two comparison movements was longer *or* shorter, was elicited by the subject. Subjects' responses were balanced by postcuing one-half the subjects to make K1 vs. K2 and one-half to make K2 vs. K1 comparisons. These changes were necessary as all subjects were blindfolded throughout the testing session.

Each subject received five trials for each of the nine experimental conditions. Distribution of these 45 trials is given in Table 25.

The standard movement (K1) and comparison movement (K2) were each set at 40 cm. The three anchor lengths used were 20 cm, 40 cm, and 60 cm, thus providing anchors less than, equal to, and greater than the standard and comparison movement length.

In addition to the 45 experimental trials, 60 catch trials were administered. The 60 catch trials were made up as follows: Of the nine experimental conditions, six involved real differences between K and A, while three

Table 25

Distribution of Trials Among the
Four Conditions

No. of Trials	Condition	Comparison
15	Preceding = AKK	2 vs. 3
15	Interpolated = KAK	1 vs. 3
15	Following = KKA	1 vs. 2
60	Assorted Catch Trials	

NOTE: K = Standard and Comparison Stimuli
A = Anchor Stimulus

conditions did not involve a difference (K1 = K2 = A). Catch trials involved comparison judgments between K and A for the six real difference conditions (A $\neq$ K1 or K2). Whether A was compared to K1 *or* to K2 was determined by counterbalanced selection for each catch trial. The six catch trial condition judgments of A vs. K, when A physically differed from K, occurred a total of 30 times. Each subject received five trials for each of the six catch trial conditions.

The remaining 30 catch trials involved recognition judgments between three movement distances, each of a different length. Only three movement distances were used throughout this experiment: namely, 20 cm, 40 cm, and 60 cm. There are six possible presentations of these three distances (e.g. 40-60-20) and each of these occurred a total of five times. Comparison judgments were requested between two of the three movement lengths. Comparison decisions were determined by counterbalanced selection for each of the 30 catch trials.

The catch trials served two purposes:

1. They provided comparisons requesting decisions involving movements other than K1 vs. K2. Hence subjects could not depend on K1 vs. K2 strategies only.

2. They prevented subjects from expecting two movements of similar length each trial.

The 105 total trials (45 experimental and 60 catch trial) were randomly separated. Subjects received 50 trials

in the first testing session and 55 trials in the second session (held on a subsequent day). Ten practice trials were given prior to each testing session. Of the ten practice trials, eight involved real differences so the experimenter could note if the subject had failed to grasp the procedure.

Data Analysis

In order to make the K1 vs. K2 judgments compatible with the K2 vs. K1 judgments, K1<K2 judgments were converted to proportions and this value subtracted from unity. Thus 0.4 judgments K1<K2 were equivalent to a proportion of 0.6 K2<K1 judgments.

The proportion of judgments K2<K1 for all three anchor positions, with each anchor size, is presented in Table 26.

Results

The proportion of judgments K2<K1 were submitted to a two-way repeated measures analysis of variance. The main effect of anchor size was found to be significant, $F\ (1,9) = 4.25$, $p<.08$, conservative F test, and $F\ (2,18) = 4.25$, $p < .035$, normal F test. A significant anchor size X anchor position interaction was also evident, $F\ (1,9) = 4.83$, $p < .06$, conservation F test, and $F\ (4,36) = 4.83$, $p < .01$, normal F test. The anchor position main effect was not significant.

The proportion of judgments K2<K1 under each anchor level, for the three anchor positions, is illustrated in

Table 26

The Proportion of Judgments K2<K1
for Each Subject Under Each Condition

Condition	Subject	ANCHOR SIZE (cm)		
		20	40	60
Preceding	1	0.2	0.6	0.4
	2	0.2	0.6	0.4
	3	0.6	0.8	0.4
	4	0.2	0.8	1.0
	5	0.8	0.6	1.0
	6	0.4	0.6	1.0
	7	0.0	0.8	1.0
	8	0.2	0.4	1.0
	9	0.4	0.8	0.8
	10	0.2	0.8	0.8
	$\bar{x}$	0.32	0.68	0.78
Interpolated	1	0.6	0.6	0.8
	2	0.2	0.2	0.2
	3	0.0	0.2	0.8
	4	1.0	0.8	1.0
	5	0.4	0.8	0.4
	6	0.4	0.6	0.8
	7	0.2	0.4	0.4
	8	0.8	0.4	0.4
	9	0.6	0.4	0.4
	10	0.4	0.6	1.0
	$\bar{x}$	0.46	0.50	0.62
Following	1	0.6	0.0	0.2
	2	0.6	0.0	0.0
	3	0.6	0.8	0.4
	4	1.0	0.4	0.8
	5	1.0	0.6	0.6
	6	0.2	0.8	0.6
	7	0.8	0.2	0.4
	8	0.4	0.8	0.6
	9	0.6	0.8	0.2
	10	0.2	0.4	0.4
	$\bar{x}$	0.60	0.48	0.42

Figure 20.

A set of a priori planned comparisons were constructed to test for both significant directional biasing due to anchor size, and significant differential biasing effects due to anchor position. Comparisons between anchor sizes *within* each condition of anchor placement (P, I, or F) constitute nine comparisons, and comparisons *between* anchor placement conditions for each anchor size constitute a further nine comparisons. Such a large number of multiple comparisons increases the chances of making a Type I error. Dunn's (1961) multiple comparison procedure,* which takes into account the number of comparisons to be made by splitting up the level of significance (α) among the planned comparisons was therefore used.**

Results of the analysis *within* each anchor placement condition were that significant directional biasing effects occurred in the preceding (AKK) condition only. The proportion of judgments $K2<K1$ with an anchor length of 20 cm, was significantly lower than both the 40 cm anchor ($p < .01$) and the 60 cm anchor ($p < .01$) judgments. The 40 cm anchor judgments in the preceding (AKK) condition, did not significantly differ from the 60 cm anchor judgments.

* Miller (1966) has used the designation Bonferroni t statistic for the same procedure.

** This test, like the multiple t ratio, does not require a prior significant over-all F ratio (Kepple, 1973; Kirk, 1968).

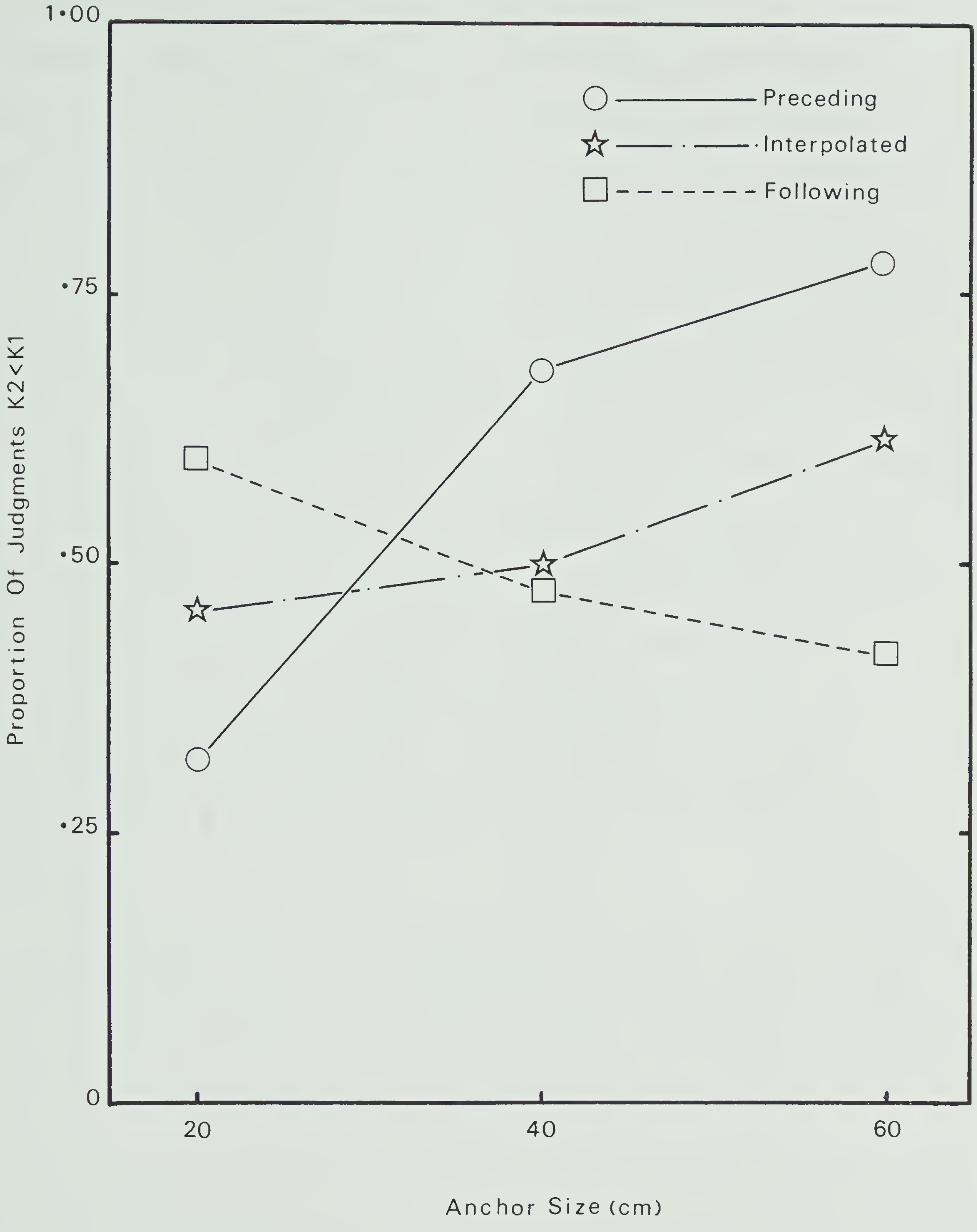


Figure 20. The proportion of judgments K2<K1 at each anchor level for the three anchor positions: P (preceding), I (interpolated), and F (following).

Results of the analysis *between* each anchor placement condition were that significant differential biasing effects occurred. The proportion of judgments K2<K1 for the short 20 cm anchor length in the preceding (AKK) condition, were significantly lower ($p < .05$) than the proportion of judgments K2<K1 for the following (KKA) condition under the same length of anchor. Conversely, the proportion of judgments K2<K1 for the long 60 cm anchor, in the preceding (AKK) condition, were significantly greater ($p < 0.1$) than the proportion of judgments K2<K1 for the following (KKA) condition under the same length of anchor. When the anchor was 40 cm in length, judgments did not significantly differ between the preceding (AKK) and following (KKA) conditions. This significant anchor size X anchor position interaction is illustrated in Figure 20.

The proportion of judgments K2<K1 for the interpolated condition (KAK) did not significantly differ from either the preceding (AKK) or following (KKA) condition judgments.

Discussion

Anchor movements presented in context with a standard and comparison movement length, caused significant directional biasing in recognition judgment. The effects of the anchor stimuli appear to be the result of a process of retroactive assimilation (Helson, 1964) rather than one involving proactive contrast (Ellis, 1971, 1973a). This must be qualified by the following considerations.

Significant directional biasing in recognition judgment occurred in the preceding (AKK) anchor condition only. Although not significant, directional biasing was evident for interpolated (KAK) and following (KKA) conditions (see Figure 20). The directional biasing effects for all three anchor placement conditions (AKK, KAK, KKA) conform exactly to the prediction outlined in Experiment 1 for a retroactive assimilation interpretation. Both the preceding (AKK) and the interpolated (KAK) conditions provided the same biasing trends for small and long anchor movements, even though the interpolated biasing effect was somewhat depressed. Generally, in both the preceding and interpolated conditions, a small anchor caused subjects to respond K2>K1 while a long anchor caused the response K1>K2, even though K1 was equal to K2.

When the anchor movement followed the standard and comparison movements (KKA), the directional biasing effects were in the opposite direction to those associated with the preceding and interpolated conditions. The directional

biasing effects in the following (KKA) condition were not significant but the general trend was quite evident. Infact, there was a significant interaction between the preceding (AKK) and following (KKA) conditions, due to the opposite directional biasing effects of the long and short anchors in those two conditions.

Overall, the results conform exactly to a retroactive assimilation interpretation. This is not too surprising as a significant retroactive assimilation effect occurred for similar anchor and standard movement lengths in Experiment 5, tested via a recall paradigm. The results, however, establish the efficacy of the KAK recognition paradigm for studying context effects in movement judgment.

One result which is a little difficult to explain, occurred in the preceding (AKK) condition when the anchor movement length was equal to the standard and comparison movements (i.e. $A = K1 = K2$). There should be no directional biasing effects when the anchor, standard, and comparison movements are all of the same length. This was the case for the interpolated (KAK) and following (KKA) conditions where mean proportion of judgments $K2<K1$ were around 0.5 chance level. A large positive time-error, however, occurred in the preceding (AKK) condition, where subjects chose $K2<K1$ 68% of the time. A negative time-error ($K2>K1$) is the usual finding in perceptual judgment studies, with interstimulus intervals of more than three seconds (Needham, 1934). The positive time-error effect found in the preceding (AKK)

condition is difficult to interpret but may be, in part, due to the small number of trials given for each condition (five trials). Conversion of the data (i.e. five judgments) into proportion of judgments K2<K1, resulted in only even numbered proportions. The chance proportion 0.5 could not be attained. Consequently, unbiased judgments which should produce the chance proportion 0.5 had to be reflected by the proportion 0.4 or 0.6, which may, in itself, introduce a judgmental bias. This does not seem likely however, as this form of bias was not reflected in similar A = K1 = K2 conditions when the anchor was placed in an interpolated (KAK) or following (KKA) position.

Placement of the anchor movement in the preceding condition (AKK) produced the greatest directional biasing effects in recognition judgment. The interpolated condition (KAK) followed a similar trend to the preceding condition, but was somewhat depressed in its biasing effects. The finding of superior biasing when the anchor preceded the standard (AKK) than when it followed the standard (KAK), supports the similar finding in Experiment 3, but is not in agreement with other MSTM studies (Craft, 1973; Craft & Hindrich, 1971). However, as was stated in Experiment 3, comparisons between such studies and the present one may not be legitimate due to the different paradigms and procedures used.

It was noted in Experiments 1 and 2 that a negative time-error effect seemed to be in evidence, causing most

judgments to be below the 0.5 proportion level. This was not the case in this study and is probably a reflection of the catch trial data. In Experiments 1 and 2 no attempt was made to control subject strategies, whereas in this study the catch trial data attempted to achieve such a control. The catch trials employed in this study seem to have been worthwhile. First, they gave the experimenter continuous indication as to whether or not a subject was following the instructions correctly, and second, they helped maintain subject attentiveness. When three different distances were presented (each being 20 cm apart), subjects were aware their recognition decisions were correct. This form of positive feedback seemed to help maintain subject interest. Indeed, of the 60 catch trials, not one subject responded with an incorrect decision. In addition, the catch trials were able to control subject strategies. This fact is supported by the fairly low interindividual variability associated with the results of the short and long anchor movement conditions (see Table 26).

GENERAL DISCUSSION

General Discussion

The retroactive assimilation effect (Helson, 1964) is the most prevalent finding in MSTM context studies. A number of researchers however, have reported conditions which did not produce the expected directional biasing associated with assimilation theory (Herman & Bailey, 1970; Kerr, 1978; Laabs, 1971; Levin, Norman, & Dolezal, 1973; Patrick, 1971; Stelmach & Barber, 1970; Stelmach & Kelso, 1973; Stelmach & Walsh, 1972, 1973). At the outset of the present series of experiments several reasons were postulated as to why directional biasing does not occur under all anchor conditions. One reason considered the possibility of proactive contrast effects (Ellis, 1971, 1973a) operating in opposition to assimilation effects. Proactive contrast effects were not only in evidence in the present series of studies, but were found to combine with assimilation effects, resulting in a decreased assimilation directional biasing effect. Contrast effects were found to occur when the anchor range included movement lengths extremely longer and/or extremely shorter than the criterion movement length. A form of perceptual illusion (proactive contrast) can therefore occur over certain movement ranges. MSTM researchers must be cognizant of a perceptual biasing effect that will alter reproduction and recognition performance but is not related to short-term memory processes.

Differential directional biasing effects were found in that criterion movements of different length were not affected to the same degree of bias by anchor movements. Small movement lengths appeared resistant to the anchor biasing effects over a wide range of anchor movement length. The finding that small movements were resistant to anchor interference effects whereas long movements were not, adds to the growing evidence that different movement lengths may result in their corresponding memorial items having different retention intervals (Duffy, Montague, Laabs, & Hillix, 1975; Laabs, 1971, 1974, 1977, 1980; Posner & Keele, 1969; Stelmach & Wilson, 1970).

Very small movements in this series of experiments were consistently overestimated and any directional biasing effects due to anchor stimuli may have been confounded with the range effect (overestimation of small distances, underestimation of long distances) which is known to occur in movement recall (Hall, 1977; Pepper & Herman, 1970; Wilberg & Hall, 1976). The range effect or central tendency effect has been well documented both within and outside of the laboratory setting. The range effect is not merely errors in estimation but represents a fundamental mode of behaviour. Griffith (1949) studied the behavior of spectators who placed "bets" on horses at the racing track. He found that the objectively poorer risks, on the basis of past performance, were overbet and the better ones were underbet by most of the people who "played" the horses.

Market analysts in the stock market (another great sphere of betting) have also noted that lower priced stocks were bid much higher than their intrinsic worth while higher priced stocks were underbid in relation to their future possibilities (Helson, 1964). These documented instances serve to illustrate that the overestimation and underestimation tendencies of judgment uncovered long ago in psychophysical studies, are not artifacts of experimental procedures or mere errors of estimation. Rather, as Helson (1964) states "they are fundamental modes of adjustment that are ubiquitous" (p. 100). A range effect may therefore replace or obscure negative shifts in constant error (CE) for extremely small movement reproduction. A similar form of range effect bias may be evident for extremely long movement lengths. However, both overestimations and underestimations occurred for the extremely long movement lengths in the present series of experiments. Hall (1977) reported that the range effect developed faster for short distances than for long distances. Hall's findings may be one explanation of why a range effect might be expected to be more prevalent with the short movements in the present series of studies.

Another reason why small movement lengths did not exhibit the same degree of biasing effects as did longer movement lengths, is the possibility of anchor ineffectiveness with small anchor movements. Ellis (1971) claimed that anchors outside a certain range cease to be effective

in a manner proportional to their intensity. With extremely small anchors Ellis (1971) found for auditory stimuli, a range of anchor ineffectiveness rather than contrast or assimilation effects.

Recognition judgments of movement length do not appear to be subject to the usual time-errors frequently associated with perceptual judgments. This statement however, must be qualified. The time-error effect on recognition judgments was investigated in Experiment 1. The extent of this phenomenon is not known however as only two interstimulus intervals and one small movement length were considered. Long movement lengths may exhibit time-error effects where small movement lengths do not. Such differential time-error effects might be expected due to differences in encoding and retention characteristics associated with short and long movements (Laabs, 1977, 1980; Posner & Keele, 1969). Further, when length of movement was included as a variable, differences in retention were found in distance conditions. That is, recall variable error (VE) has been shown to increase as the movements get longer (Diewert, 1975; Hall & Wilberg, 1978; Kerr, 1978; Laabs, 1977; Posner, 1967; Posner & Konick, 1966; Roy & Kelso, 1977). The dependent variable, VE has been used as an indicator of the strength of the memory trace (Laabs, 1973), and so a time-error, indicating a memorial weakening, might be expected with long movements.

Many of the MSTM studies that report assimilation effects

due to interpolated anchors did not control the subject's attentiveness to the interpolated anchor movement. Some of these MSTM context studies required the interpolated movement to be remembered, others did not. Although control of the subject's attentiveness was not considered in many of the MSTM studies, assimilation effects prevailed. This was not the case however, in the present series of experiments. Controlling subject strategies and attentiveness through the use of catch trials was an important consideration. Ellis (1971) found the instruction to judge or not to judge the anchor stimulus, had a bearing upon the amplitude of the directional biasing. The instruction factor is not easily quantifiable, but, nevertheless, must be considered in theoretical explanations of context effects. Whether instructions affect attention (and thereby, perhaps, input) or response systems remains unresolved.

The KAK recognition paradigm utilized in this series of studies provided similar results to the more frequently used recall paradigm of reproduction accuracy. Both the recall and recognition paradigms appeared sensitive to the directional biasing effects of the anchor movements. In fact, the KAK recognition paradigm would seem to be a more powerful test than reproduction accuracy. For example, the KAK recognition procedure was sensitive enough to elicit significant directional biasing effects with small movements in Experiment 3. With the reproduction accuracy method,

nonsignificant directional biasing was found for similar movement lengths and conditions.

A difference in sensitivity between the reproduction accuracy and KAK recognition paradigms, may not be the reason why short movement lengths elicited different results in the two procedures. There may be a difference in recognition and recall processes for small movement lengths. Whether recognition processes differ from recall processes is not clear. One view is that recognition does not require the overt retrieval of the stimulus item. Therefore in recognition the subject relies on discriminative attributes whereas in recall it is both the discriminative and retrieval attributes that are acted upon (Underwood, 1969). The dual-process hypothesis is also based upon differences between recall and recognition processes (Kintsch, 1970; Anderson & Bower, 1973). According to the dual-process hypothesis, recall consists of a two stage process, while recognition involves only one stage and is actually a subprocess of recall. Recall consists of a two stage process; a search process aimed at locating potential material in memory and a subsequent recognition test to ascertain whether that information is what was actually being sought. Recognition only involves the second stage. Lockhart, Craik, and Jacoby (1976) argue that there is no real difference between the recall and recognition process. Lockhart et al (1976) in their levels of processing model propose that two basic modes exist for both recall

and recognition. The first is a reconstruction process in which some approximation to the initial form of the encoded stimulus is generated in the perceptual/cognitive system. The second process is scanning, which is the search of recent episodic traces for the presence of some salient feature of the probe item to be retrieved or recognized. Since the same two retrieval modes exist for both recall and recognition, Lockhart et al (1976) argue that recall and recognition are basically the same process.

The present studies, although not suggestive of distance reproduction and recognition being essentially the same process, do indicate that both distance reproduction and recognition are influenced in a similar manner by anchor movements.

The KAK recognition paradigm proved to be an effective way of studying the effects of context on the recognition of movement distance. Variations within the KAK paradigm are also possible. One change that may be worthwhile is the dependent variable, proportion of judgments. The proportion of times the standard is judged to be greater than each variable (or vice versa) is the usual measure obtained with the method of constant stimuli (Ellis, 1971). However, other methods have been utilized, one of which is response latency. Henmon (1906) was among the first to observe that more difficult decisions take longer to make. Anchor stimuli apparently lead to both changes in the perception of a stimulus (contrast) and changes in the

memory of the stimulus (assimilation). A corollary to this might be that response time would reflect the effectivness of an anchor in determining apparent differences between two objectively equal stimuli in a recognition situation. Stated more formally: it is predicted that the more extreme anchors in a KAK recognition situation will lead to shorter response times than those less different in size to K1 and K2. The longest response will coincide with the mid-point of the anchor series (i.e. when A=K1=K2). Using both auditory and visual stimuli, Ellis (1971, 1972) utilized response times in the KAK recognition paradigm. Response times not only provided reliable results but Ellis suggested they were often a more discriminating measure than judgment proportions.

Another measure that may prove worthwhile when studying anchor biasing effects is d', a measure of a subject's sensitivity. It is possible to obtain a measure of d' through signal detection theory. Signal detection theory was independently developed by a number of investigators concerned with explaining the decision making behavior of observers faced with the task of deciding whether faint signals had or had not occurred. The most well known model is that proposed by Tanner and Swets (1954). From a knowledge of an observer's Hit/Miss and False Alarm rates, various parameters may be estimated. The two most commonly quoted parameters are d' and ß, which refer, respectively,

to sensitivity and response criterion. A subjects response criterion may change on the basis of such factors as a priori probabilities of signal and no signal; experimental instructions (e.g. be strict or lax in judgment); and pay-offs associated with being right or wrong. Sensitivity, on the other hand, is claimed to be relatively invariant, being affected primarily by signal: noise ratios (Green & Swets, 1966). There is some doubt, however, concerning the invariance of a subject's sensitivity (Broadbent & Gregory, 1963; Treisman & Geffen, 1967). Treisman and Watts (1968) incorporated the method of constant stimuli with signal detection theory. With a slight adjustment signal detection theory can be applied to the KAK (method of constant stimuli) recognition paradigm. The point of applying signal detection theory to the KAK paradigm is to discover whether sensitivity (d'), or the response criterion (ß) is altered as a function of interpolated anchors. It may be that anchors alter d' which suggests they bring about a change in sensitivity, thereby providing another means by which anchor effects might be measured and analysed.

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APPENDIX A

Context Effects in Sensory Judgment

One of the major researchers to influence the development of psychophysics was Fechner (1860). Although involved in metaphysical issues concerning the mind-body problem, Fechner developed many methodological techniques which helped form the basis of modern empirical psychology.

The major point of interest at this time was to define the relationship between stimuli of known physical characteristics and the subjective sensations which they evoke. From Weber's Law, Fechner proposed a logarithmic relationship between stimuli and sensations. This idea stood for almost a century before Stevens (1957, 1961) expressed the strongest challenge to this, with the contention that a power function better describes the relationship. The rationale for psychophysical investigations was that a subject may be treated as some kind of meter which may be calibrated rather like any electrical measuring device. A voltmeter, for example, may be calibrated by applying to it known voltages and marking each deflection of its needle, until a scale is formed. One would then possess a relatively invariant machine which would behave in a predictable fashion.

Unfortunately, it is less easy to scale human subjects, for a great deal of variation occurs, both among the responses obtained from the same stimulus on different occasions, and among different subjects. In addition, the methods used themselves lead to differences; the method of

absolute judgment, for example, yields a different relationship to that found when magnitude estimation, or fractionation methods are employed (Ellis, 1971).

Context Effects

It has been asserted that human judgments are relative rather than absolute. This idea has been called "psychological relativity", which has been paralleled to Einstein's Theory of Relativity (Helson, 1964; Corso, 1967). The analogy drawn between the two theories is of limited value. Einstein's theory states that measurement of mass, space and time are relative to the speed of light. Hence physical relativity has as its standard the speed of light which is a reasonably invariant yardstick, that may be independently measured. Psychological relativity, however, involves comparison with a number of past and present experiences, which means the "standard" is always in a state of change. Further, it can only be inferred from the judgmental process and not independently of it.

Psychological relativity has usually been discussed under the headings of either frames of reference, or *context effects*. The latter heading will be used throughout this exposition. Both terms refer to the influence of relevant past or present stimulation upon the on-going judgments, made by an organism (Philip, 1949). The present study is concerned with context effects, that is, it concentrates on deviations in the judgment of a stimulus which may be attributed to the context in which it occurs.

The idea that judgment depends not only upon the object to which the observer directs his attention, but also upon the presence of surrounding context, is admirably highlighted by Ellis (1971). Ellis quotes the Times (2.5.69.) newspaper correspondent Geraldine Keen, who reported on the sale of pointilliste paintings. She commented that a painting entitled "Trois Danseuses Rouge" probably suffered somewhat from the presence of a finer work, (Degas' "Danseuses Bleues") and went for (only) $180,000. The moral would seem to be, do not enter a painting in a sale in which a similar but superior piece of art is also for sale, for it will not be as well received, as it otherwise might be.

Although examples of context effect may readily spring to mind, a consistent definition of a context effect is more difficult to find. Most of the definitions fail to encompass much of what is known about context effects. Magaro (1966), for example, showed that an imagined context can alter judgements; Black and Bevan (1960) and Bevan and Pritchard (1962), showed that a subliminal context (which the subject was not dealing with) was effective in altering judgments of supraliminal stimuli; Parducci (1965) has demonstrated that "addition or deletion" of stimuli is not a necessary requirement, since alteration in the frequency with which members of the subset are presented, may distort judgments; and lastly, Tresselt (1948) has suggested the context may be established before an observer

enters the laboratory.

Ellis (1971) probably offers the most adequate definition of context: "a context effect is any systematic shift in the judgment of a stimulus, or stimuli, which results from alterations in the range or frequency of relevant stimuli to which an observer has been exposed" (p. 4). This definition normally refers to manipulations within an experimental setting, but it also takes into account the experiential history of the subject.

Stimuli which constitute the context are often referred to as *anchors*. Anchors then, are stimuli which induce systematic distortions in the judgment of other stimuli. The effective action of anchors is limited to either of two processes: they may attract (assimilation) or repel (contrast), other judgmental stimuli. To take a sporting example, a basketball player who is a short man, when walking between Kareem Abdul-Jabbar and Wilt Chamberlain (two tall men, both over 7 feet in height), might be judged taller than he is walking alone (assimilation); or he may, in the same context appear even shorter than he actually is (contrast). The two tall basketball players constituting the context, are the anchors.

Context effects in perceptual judgment have been studied since before the turn of the century and constitute a major portion of the research carried out in psychophysics over the past 80 years.

In the late 1960's context effects were first studied

in the area of motor movement. The experimental paradigms, rationale and context theories, based on a wealth of psychophysical research, have been adapted to motor short term memory (MSTM) studies in an effort to explain the processes involved in the short term retention of movement information. The applicability of such a transfer is questionable; the experimental paradigms and units of analysis employed in MSTM studies are cause for concern in themselves,* however, the accepted transfer of established psychophysical theories of context effects to account for 'error' performance scores, and hence memorial changes, in motor reproduction accuracy tasks, is of more importance.

MSTM researchers have adapted the established psychophysical experimental techniques to study the retention of movement information. To explain the results of such studies, MSTM researchers have relied on both the established context theories and prominent psychological theories associated with human memory (i.e. interference and decay theories). Combining context and human memory theories new models and theories have been formulated to account for the processes involved in motor movement retention (Laabs, 1973; Pepper & Herman, 1970; Stelmach & Walsh, 1972, 1973). It is the authors contention that the established psychophysical context theories may not be totally applicable to

* The units of analysis involved in MSTM research will be discussed later.

MSTM studies in their original form. Indeed, the established perceptual context theories are not themselves without criticism. Further, the psychophysical technique of 'method of adjustment', used in MSTM research studies, may not be the most efficient way to study context effects with motor movements.

This thesis proposes the use of an experimental paradigm first suggested by Underwood (1966) and later developed by Ellis (1971, 1973a). It is basically the psychophysical technique of 'method of constant stimuli', which has distinct advantages over the 'method of adjustment' (Plutchik, 1968). In order to familiarise the reader with the rationale for the acceptance of this paradigm it is necessary to review and evaluate the various theories of context effects. A brief review will be presented illustrating the major developments of theories to account for context effects in sensory judgement. The established context theories and perceptual judgment findings will be evaluated, and their suitability to explain MSTM research analysed.

Theories of Context Effects

The whole process of judging successive stimuli may be described in terms of Gestalt theorie. Koffka (1922), in discussing perception, makes the assertion than when an observer is making a comparative judgment, two discrete objects are not perceived, but instead a step or gradation

is formed and so one object is judged greater than the other. The first stimulus of the pair, a lifted weight for example, establishes a level of potential which tends to persist for a time. The second weight produces a change in this level, a shift of potential upward or downward. It is this shift that gives rise to the judgment of "greater", "equal", or "less".

Koffka's theory was examined by Guilford and Park (1931) who used a method of inserting a third stimulus (anchor) between the standard and its comparison stimulus. This is the psychophysical "method of constant stimuli" with interpolated anchors. The introduction of the interpolated anchor stimulus was to interfere with the comparative judgments by breaking up the simple relationship between the pairs to be judged. The anchor was to be more than a simple distractor item for the subject, but had to act to destroy the direct continuity which existed between the two stimuli of a pair. The choice of stimulus used in the Guilford and Park study was that of lifted weight. The interpolated anchor was also a lifted weight, one distinctly different from the weights of the pair to be judged. The choice of weight for the interfering anchor was based on the reasoning that it would be a poor distractor because of its similarity to the other two stimuli, and yet, it should operate directly upon the shift of potential.

The results of the Guilford and Park study were twofold: First, a heavier and lighter weight interpolated between the

standard and its comparison weight enlarged the differential limen, making discrimination poor, and second, they shifted the psychological values of the comparison stimulus relative to the standard stimulus. In general, a heavy interpolated weight tended to decrease the impressions of the comparison stimuli and a light interpolated weight tended to increase them.

The Guilford and Park study serves as a classic in so much as it heralded the vast number of studies that have occurred over the past 40 years involving the effects of interpolated anchors on comparative judgments.

Time-Error Theories

If two equal stimuli are presented successively for the purposes of comparison with respect to some psychological dimension, then the stimulus presented second will appear greater, louder, higher, longer, as the case may be. Fechner (1860) first noted this phenomenon when he found the second of two weights was often judged heavier than the first, and he attributed this to the possibility that the second was, in fact, being compared to a degraded image of the first stimulus. Hence, if the two were identical, the second would appear heavier than the first. This is known as negative time-error. The opposite (i.e. the first seeming heavier than the second weight) is known as positive time-error. The usual method of calculating both the size and direction of time-error when the method of constant stimuli is used, is to subtract the standard from

the point of subjective equalitity.*

$$TE = PSE - St$$

where TE = Time-error

PSE = Point of subjective equality

St = Magnitude of the standard stimulus

In most cases, a negative time-error is found, which grows monotonically with increasing temporal separation between the standard and comparison stimuli (Needham, 1935a). Positive time-errors appear when both the standard and comparison are low in value (Fernberger, 1931; Needham, 1935b); and when the time interval is below 3 seconds (Kohler, 1923).

Various attempts have been made to account for the time-error phenomenon. Fatigue was one reason put forward by Martin and Muller (1899) for the falling-off in effective comparison value of the first stimulus. This would be plausible enough for intensity of weight used in the Muller and Martin study, but the time-error appears in other dimensions and modalities. With weight stimuli, fatigue would cause the second member of a pair to appear heavier, whereas in sound, where the time-error is equally marked, fatigue, if it operated at all, would cause the second member to appear softer (Pratt, 1933).

* When an observer attempts to match a variable stimulus as close as possible to a standard stimulus, the point where the observer considers that the two quantities are matched is called the point of subjective equality.

Borak (1922) was able to dispose of another theory popular at this time. The physiological effect of the standard stimulus was thought not to completely disappear, with the result that an effective increment is added to the comparison stimulus, and so favour a judgment in the direction of the increase. Since the physiological effect presumably decreases with the passage of time, a longer interval between standard and comparison should tend to return the judgments more nearly to symmetrical distribution. Borak found the exact opposite. With increase of time interval between standard and comparison, the preponderance of greater judgments becomes even more pronounced.

During this period, the most common explanation of time-error revolved around a "sinking trace" (Kohler, 1923) or "fading image" (Fechner, 1860). When a judgment is made upon the second stimulus in terms of the first, the standard is already past and gone. The comparison must therefore be based upon some sort of imaginal revival of the standard stimulus. If this is true, it is only natural to suppose that the revived image is less intense than was the original impression. The comparison stimulus is therefore always judged against a lowered standard, and so *greater* judgments outnumber the *less* and the points of subjective equality uniformly occur below the level of objective equality.

Borak and others had suggested that the neurological trace of the first stimulus combines with the incoming second stimulus and thus causes an enhancement in the

direction of the increase. However, Kohler (1923) defended the view that the standard stimulus retains its relative independence and forms a physiological trace level against which the second stimulus acquires its effective value for comparison. (This view is very much in line with Koffka's ideas relating to perception, previously mentioned). Kohler defended this view because it accords well with the increase in the amount of negative time-error with lengthening of the time interval between standard and comparison.

Lauenstein (1932) proposed a modification or enlargement of Kohler's trace-theory. Using the method of constant stimuli with interpolated anchors of Guilford and Park (1931), Lauenstein found when the interpolated anchor was a stimulus of the same modality but considerably stronger than the standard, then, instead of a negative time-error, a positive time-error appeared, i.e. the standard appeared greater than the comparison stimulus. When a weaker interpolated anchor stimulus was used, the usual negative time-error returned. Lauenstein therefore assumed that, since the introduction of a strong interpolated anchor stimulus produced a preponderance of judgments of standard less than the comparison, the physiologically effective trace must be regarded at any one moment durings its course, not as a sinking trace, but rather as a process of *assimilation* going on between the trace and the neural effects of surrounding stimuli.

Lauensteins assimilation theory states that when a strong interpolated anchor stimulus is presented between

the standard and comparison stimuli, the standard assimilates with the anchor to produce a new trace level against which the comparison stimulus is judged. Taking this to its ultimate conclusion, Pratt (1933, 1935) suggested if no anchor stimulus is included, then one must assume, according to Lauenstein's assimilation theory, that assimilation to zero must be taking place. In other words, assimilation to zero must produce a lower trace, and hence an increased preponderence of greater judgments than assimilation to any value above zero. Pratt (1933) provided evidence which indicates that such is not the case. Her results supported Lauenstein's theory apart from the condition where no anchor was presented. This condition produced a point of subjective equality which was in fact higher than a condition involving a lesser interpolated anchor stimulus.

Pratt (1933) concluded her study by suggesting the course of the time-error, with the passage of time and with different time intervals, is anything but a simple function. Her results, she suggested, are reported as evidence that the issue between *assimilation* and *sinking* is still open. To explain the results of the no anchor condition, she postulated that when a background or interpolated stimulus is involved in the set, the process of assimilation takes place. When, however, there is no interpolated stimulus, nor appreciable background, the trace merely sinks.

Pratt (1936) later proposed a theory of negative

time-error based upon Thorndike's Law of Disuse. It is, however not very different from those previously advanced, in that it involves the assumption that the strength of a trace diminishes over time. When interpolated stimuli occur, Pratt argued that they interact with the already declining standard trace and cause it to diminish even more rapidly.

Assimilation theory took a set-back in 1935 when Needham (1935b) postulated that the interpolation effect would become greater as the time interval between the standard and comparison stimulus is increased. This hypothesis was based on the idea that if assimilation is the determining factor, then there should be 'more' assimilation with longer time intervals. The results of Needham's study involving auditory stimuli, directly contradict this hypothesis. Needham concluded that as the time interval lengthens, the interpolated stimulus becomes more and more remote (temporally and phenomenally) from both the standard and comparison stimulus, and its effectiveness as a 'disturbing factor' decreases. Needham offered a word of warning, and suggested his results were not a denial of such concepts as that of assimilation, rather, his results suggest the need of a thorough analysis of the process of judgment in more terms than those of easily adapted physiological postulates. Needham stated:

> The comparison process, together with other forms of the so-called higher mental processes,

> is not a simple affair; the determinants are numerous, variability is the rule rather than the exception, and a limited physiological hypothesis such as that of sinking-trace (Kohler) or of assimilation (Lauenstein), implies a constancy and a simplex determinism which belie the true state of affairs. (p. 772)

<u>Adaptation Level Theory</u>

One major theory which has attracted most attention is Helson's adaptation-level theory. In 1947 Helson published the first of many papers (1947, 1948, 1959, 1964), to introduce his theory of adaptation-level as a frame of reference for prediction of psychophysical data. Helson (1964) did not intend its application to be limited to the area of psychophysics, rather, his intention was to provide "a single theoretical basis...for ordering and understanding many different aspects of behavior" (p. 14).*

Helson studied the results of a great number of psychological research experiments involving many different sensory modalities. He became aware of the unique human ability to adapt to the environment very quickly. Adaptation is seen as the mechanism for acquainting us with the environment. If the same stimulus continues, adaptation

* This thesis is only concerned with context effects in sensory judgment and so other areas to which adaptation-level theory has been applied, will not be considered here.

gradually counteracts its effects to the point where it may no longer be sensed or its qualities become neutral (Helson, 1964). Thus, the results of many of the early studies involving changes in colour perception over time (Helson, 1938), could be readily explained. Helson (1938) found that, by presenting an object under different illuminations against various backgrounds, judgments of its hue, saturation and lightness varied as a function of these manipulations. Under coloured illumination, dark greys viewed against a grey background were judged to be blue-green, whilst light greys were judged red or bluish-red. At an intermediate point in reflectance, however, the sample appeared achromatic. Helson termed this point the adaptation reflectance, which he found was predictable from a knowledge of the various parameters by the formula:

$$A = K(\overline{X}Y^3)^{\frac{1}{4}}$$

where A = adaptation point

K = a constant

Y = the reflectance of the background

and $\overline{X}$ = the logarithmic mean of the series of albedos

From this work Helson was able to extend the weighted log. mean definition of the adaptation-level, firstly to psychophysical judgments in other modalities (1947, 1948) and later to other areas of psychology (1959, 1964). The general theory of adaptation-level has been described more simply by many authors (Guilford, 1954; Underwood, 1966; Upshaw, 1969); but it is necessary here to redescribe the

theory for parts of it, which are important to subsequent experiments, have usually been ignored.

Helson (1947) defines adaptation-level in the following manner: "For every excitation-response configuration there is assumed a stimulus which represents the pooled effect of all the stimuli and to which the organism may be said to be attuned or adapted" (p. 2). This value is called adaptation-level and is subject to change, "There is an adaptation-level for every moment of stimulation. It is a function of all the stimuli acting upon the organism at any given moment as well as in the past" (Helson, 1947, p. 3). Adaptation-level constitutes a reference point against which an incoming (focal) stimulus is compared. Due to a changing adaptation-level (being assimilated towards each new stimulus) the judgment of a stimulus will vary as the difference between it and the current adaptation-level alters. The simplest sensory experience is seen as a complex variable containing focal, contextual, and residual components. The adaptation-level is therefore seen as the resultant of at least three sources of stimulation:

(i) residual (pre-experimental experience);

(ii) contextual (the total array, past and present, presented within an experimental session);

and (iii) focal stimulation (the stimulus being attended to at the moment).

The pooled effect of these three classes of stimuli determines the prevailing adaptation-level. The adaptation-

level is attracted towards each contextual force through this dynamic pooling, but their influences are by no means equal. The three sources of stimulation are weighted differentially in proportions which must be determined by empirical means. This leads us to the procedures for calculating adaptation-level.

The adaptation-level may be derived by observing the value of the stimulus rated 'medium', when category scaling is employed,* or observing the point of subjective equality when the method of constant stimuli is used. Helson has, however, derived various formulas, based largely on an acceptance of Fechner's logarithmic law, to predict this point. These are termed weighted log mean definitions of adaptation-level. That is, ignoring residual effects, the adaptation-level roughly corresponds to the geometric mean of a series of stimuli being judged.

$$\log A = \log K + \frac{\Sigma \log Xi}{n}$$

where A = Adaptation-level

K = Constant

Xi = the stimulus series

n = number of stimuli comprising the series

When an anchor stimulus is introduced the equation becomes:

$$\log A = \log K \left[\frac{(K \Sigma \log Xi/n) + \log C}{K + 1.0} \right]$$

* An observer subjectively categorises a set of stimuli within a known scale.

Here the symbols have the same meaning as the previous equation with addition of C, referring to anchor value, and two more (K) constants. To take account of the order of presentation of anchor and each series stimulus, and the difference between each value, the constant K is reduced to two components c and d. The former was found to be 0.75 when the anchor preceded each series stimulus. The formula for calculating the adaptation-level when the method of constant stimuli is employed is:

$$\log (A+0.75d) = \frac{(3\Sigma \log X_i/n) + \log C}{4}$$

This adaptation-level corresponds to the point of subjective equality. When the standard precedes each comparison stimulus the 'd'factor (cxd) remains, but when the order of presentation is reversed, this factor is eliminated.

Helson (1964) presents a number of other equations to cover such contingencies as differential frequency of presentation and different scaling methods. He includes the concept of adaptation-level into reformulations of Fechner's Law and Stevens Power Law, but this will not be considered here.

Other definitions compatible with adaptation-level theory have been put forward by Behan and Bevan (1961) using a 'power mean', and Parducci, Calfee, Marshall, and Davidson (1960) using the 'median'. The most common definition is that of the 'log mean', but no matter which definition

is used it is evident that adaptation-level is a single value. The definition of adaptation-level as a weighted mean immediately implies that every stimulus displaces 'level' more or less in its own direction, providing that counteracting residuals are not operative. If the stimulus presented is above the momentary residing level, then adaptation takes place to move the level upward. Conversely, if the stimulus is below the level, adaptation takes place to cause the level to move downward, and if the stimulus coincides with the level then no adaptation takes place. It also follows, that repeated stimulation negates itself to some degree by reducing the distance from the adaptation-level.

To summarize: Adaptation-level theory involves the assumption that judgment may be understood by reference to one value (adaptation-level) which represents a pooling of past, contextual and focal stimulation. It is a neutral point which shifts along a continuum in the direction of each new stimulus which receives a weighting dependent upon whether it is part of the series under scrutiny or an extraneous stimulus. Judgments are made relative to the prevailing adaption-level and consequently alter as it changes.

Criticisms of Adaptation-level Theory

The major criticism against adaptation-level theory was delivered by Stevens (1958) who argued quite

persuasively that the context effects observed and predicted by adaptation-level theory were the result of a "semantic adjustment", rather than a genuine perceptual shift. Stevens argues that when category scaling is used the context effects might be due to a change in modulus. Category scales involve a range of epithets, e.g. very light at the lower end, and very heavy at the upper end. Stevens contends that the introduction of anchor stimuli causes a change in the application of the extreme adjectives. For example, if a series of gram weights were judged on a scale ranging from very light to very heavy, and then a church bell was introduced into the series to be judged on the same scale, clearly, the church bell will be assigned to the topmost category and, in order to be consistent, the gram weights will be put in the lowest category. One might infer that a contrast effect had occured, since the gram weights are placed in lower categories, but, obviously, a change in modulus is the more likely explanation. Thus, given a limited response range, subjects are forced to assign stimuli to different categories when an extreme anchor is introduced, and therefore it may be erroneous to conclude that they then perceive them any differently.

The problem outlined above can be overcome. It would seem that data from category judgments are confounded by at least two factors operating in the same direction. One, is possibly a genuine shift in perception, due to context, and the other is a semantic shift arising from the use of

that particular scaling method. By employing the method of constant stimuli category judgments are eliminated and so too are semantic adjustments. The loss of category scales with the method of constant stimuli would not present a problem as adaptation-level is identified with the point of subjective equality.

Another criticism of adaptation-level theory was levied by Ellis (1973b), who noted that adaptation-level theory contains no provision for dealing with temporal variables. Helson (1964) attempted to qualify this omission in his discussion of time-error phenomena. However, he relies heavily on Needham's (1935a) explanation of the fact that lengthening the interstimulus interval increases the propensity of positive and negative time-error.* Needham theorised that, as the interstimulus interval is lengthened, so the effects of preceding stimuli are enhanced. In adaptation-level theory terms, as the interstimulus interval is lengthened, the comparison will be made less on the basis of the intensity of the standard and more on the prevailing adaptation-level.

Ellis (1973b) attempted to evaluate Helson's (1964) predictions concerning both the effects of residual contexts and whether any such predisposing influences increase as the interstimulus interval becomes longer. Using three auditory stimuli, Ellis' results support Helson's

* Interstimulus interval is the time interval between offset of one stimulus and on-set of a subsequent stimulus.

prediction that residual context effects influence the time-error. However, when the interstimulus interval was varied through 1, 4, and 7 seconds, the results of Ellis' do not correspond to Helson's views on temporal effects. Instead of a divergence in curves, predicted from Helson's theory, the three conditions are subjected to the same downward trend, suggesting a tendancy toward negative time-error. It would appear that far from enhancing the effects of a residual context, increasing the interstimulus interval between standard and comparison dampens it and causes some other process to occur. This may be akin to the fading image or sinking-trace concept mentioned earlier, or indeed, as Ellis suggests, it may be the result of a change in reception sensitivity to the comparison stimulus rather than any alteration in the memory image of the standard.

Range-Frequency Model

Parducci (1963, 1965) proposed an alternative explanation of category judgments which states that, "Instead of comparing each stimulus with a single value, adaptation-level, the subject compares each stimulus with a set of category limens. This set is itself an average of two other sets, the hypothetical range and frequency limens" (1965, p. 418).

Parducci (1963) suggests the adaptation-level corresponds to a point which is the compromise of two influences: (i) the median stimulus, and (ii) the mid-point of the range.

The median takes account of alterations in the frequency with which stimuli are presented; and the mid-point reflects the influence of extraneous anchors.

The range-frequency theory was developed further by Parducci (1965). He suggested an observer uses the end stimuli to divide the response categories available to him, equally through the range. The observer also attempts to use each category for a fixed portion of his judgments so that, with changes in the frequency of occurrence, the category limens must change.

The compromise between these two tendencies is characterised by the mean of the frequency limens and the range limens. Parducci (1965) tested his theory using squares as stimuli. The range-frequency theory was found to hold for a number of stimulus distributions, and provided better fits than adaptation-level theory.

Sandusky and Parducci (1965) and Parducci and Perrett (1967) added to the development of the range-frequency model to category judgments by including a differential weighting factor to account for alterations in the spacing of stimuli.

Criticisms of the Range-Frequency Model

Parducci (1965) claims the range-frequency theory provides a more adequate account of category judgment than adaptation-level theory. The application of the model has, admittedly, been effective. The range-frequency theory

predicts minor departures from linearity which adaptation-level theory fails to do. The theory has its limitations however, as it fails to encompass more than category judgments. This is perhaps unfair since Parducci only intended it for that purpose, but nevertheless, as a general theory of context effects in judgments, it is inadequate.

Other Theories and Models

Kinchla and Smyzer (1967) put forward a diffusion model of perceptual memory. A model, based on Green and Swets (1966) theory of signal detection, is presented, based on the perceptual process through which an observer compares two consecutively observed stimuli. Emphasis is placed on the manner in which a memory of the standard is maintained until the comparison stimulus is observed. Once the sensory value of the standard is stored in memory, it is 'diffused' or modified through a random walk process until it is needed for a comparison match with a subsequent stimulus. It is argued that the role of this perceptual memory process provides the primary distinction between detection and recognition tasks.

Like many of its predecessors, the biased random-walk model is, clearly, limited in that it can only account for negative time-error. There is ample evidence for the occurrence of positive time-error which constitutes a major flaw in the diffusion model.

A correlation and regression model put forward by Johnson and Mullally (1969), in many ways resembles adaptation-level theory. Based on Johnson's (1955) Generalization Theory, it states that judges attempt to correlate their judgment continuum with the stimulus continuum. The correlation between the two continua is usually imperfect, which may account for the central tendency phenomenon (low stimuli judged higher and high stimuli judged lower). When extraeous anchors are introduced they form part of the stimulus continuum and, as such, are included in the correlation. This leads to the apparent displacement of judgments of the original series.

Like Parducci's range-frequency theory, the correlation model is designed to account solely for category judgment data. The model also suggests frequency would be irrelevant in category scaling judgments; but Parducci (1963, 1965), has clearly demonstrated the importance of such manipulations on judgment.

Overview

Not one of the theories which have been reviewed is without flaw. Further, comparisons between theories, to determine which has greatest predictive power, is virtually impossible. This is due, in part, to the different measures of performance used by each theorist. For example, Helson uses the stimulus value, which, on average, is placed on the

medium category; Parducci examines judgment shifts by locating alterations in category limens; and for Johnson the correlation coefficient and regression slope between stimuli and judgment, are indices of shifts in performance.

Parducci's range-frequency theory and the correlation and regression model of Johnson's may be eliminated from general discussion, since they are both explicitly confined to category judgments which appear to be the consequence of compound events (Stevens, 1958). Further, category judgment paradigms have not been involved in MSTM research studies; consequently, reference to such theories to explain MSTM research results, would be unfounded.

Time-Errors

The time-error was first described, named, and discussed by Fechner (1860). More than a century of research has achieved little in the way of explaining this 'error', which has been found to change with experimental conditions in ways that well merit its characterization by Hellstrom (1979) as "a particularly elusive phenomenon" (p. 460).

The study of time-error has given rise to numerous theories, many of which fail to account for the bidirectional time-errors found in some experiments. Theories which can account for both positive and negative time-error (Michels & Helson, 1954) cannot however, explain another aspect of time-error studies: namely, the fact that one often obtains both positive and negative time-errors for the same

stimulus pair, depending on the temporal separation. Kohler (1923) and others (Ellis, 1971, 1972; Pratt, 1933; Underwood, 1966) have noticed a reversal in the direction of time-error as a function of the intervening time. Intervals of less than 3 seconds commonly lead to positive time-error, whereas thereafter, negative time-error prevails. The upshot of this is that there is *no* adequate explanation of time-errors. It may be that there is more than one process at work, and that a complex or compound theory is required to successfully explain all the findings.

Motor Short-Term Memory

In the previous section the main perceptual judgment context theories, together with time-error theories, were reviewed. The importance and applicability of these theories will now be reviewed in relation to findings in MSTM research.

The Measurement of MSTM-Unit of Analysis

The typical experimental paradigm employed in MSTM research was previously outlined. Basically, a criterion movement is presented and later reproduced (method of adjustment). The performance measure typically employed in such studies is reproduction "error". Forgetting has been quantified by three measures of error: constant error (CE) which indicates the direction of the difference between a reproduction and the true or physical value of

the standard; absolute error (AE), the absolute value of the deviation from the criterion; and, variable error (VE), which indicates the spread or dispersion of a set of reproductions. Although three error measures are often reported, it is slowly becoming accepted to report only CE and VE.* The reason for eliminating AE is because CE and VE are relatively independent measures, whereas AE can be correlated with one or both of them (Schutz & Roy, 1973).

A controversy exists as to what CE and VE measures represent in terms of retention characteristics of a to-be-remembered item. That is, there is no general consensus as to what processes or factors the two measures represent (cf. Laabs, 1975, and Marteniuk, 1975). This is due, in part, to different theories of the nature of MSTM and the processes involved in forgetting (cf. Laabs, 1973, and Pepper & Herman, 1970). It is therefore proposed to accept the rationale of Laabs' (1973) views on CE and VE. CE is proposed as an index of perceptual processing and hence will reflect any directional biasing, while VE is seen as an index of forgetting for two reasons: (i) VE is reduced with practice in psychophysical judgements (which is akin to strengthening of the memory trace), and (ii) VE is more responsive to changes in processing capacity in MSTM than CE.

* Henry (1974) has introduced a fourth measure of error, the total variability (E), which is a measure of the total variability of the subjects' scores around a target value (Roy, 1976). However, the eventual place as a research tool is at present unknown.

Time-Error Studies

Although never specifically studied under the rubrics of time-error, many MSTM studies have infact required recall of a movement item after various unfilled time intervals. Several MSTM researchers have reported a significant negative shift in CE over an empty retention interval (Herman & Bailey, 1970; Kelso, 1977; Pepper & Herman, 1970). This is in line with the typical finding of negative time-error for unfilled intervals of more than 3 seconds in perceptual judgment studies (Needham, 1934). Nonsignificant effects are reported in a number of MSTM studies involving empty retention intervals, but CE trends are in the negative direction (Burwitz, 1974; Hagman, 1978; Keele & Ells, 1971; Laabs, 1973; Marshall, 1972; Roy, 1977; Stelmach, 1970; Stelmach & Walsh, 1972; Stelmach & Wilson, 1970; Williams, Beaver, Spence, and Rundel, 1969). Laabs (1979) concludes that negative time-error, although relatively weak, is nevertheless, well established in MSTM studies.

Time-errors are not only well established in perceptual judgments, but are extremely strong in effect (Pratt, 1933). Comparing the time-error effects in perceptual judgments with those of MSTM may not be a viable consideration as the relatively weak effect of time-error found in MSTM may be due to the experimental paradigm employed in motor memory research. The inferences made from MSTM studies involving unfilled retention intervals with respect to time-error may

not be justified. The term time-error refers to the common finding that subjects, when faced with the task of comparing *two* physically *equal* stimuli that are presented in succession, separated by a time interval, report that the stimuli are different. The MSTM studies outlined above, did not involve the presentation of *two equal* stimuli; nor were they recognition experiments. A slight degradation in the reproduction of a standard may not prove to be significant, whereas, the same slight degradation may be enough to elicit total biasing when comparing the standard with a subsequent stimulus in a recognition paradigm.

No MSTM study has specifically studied the effects of time-error in the strict sense of the definition.

Range Effect

A major problem in the examination of the short-term retention of information is that the only method of assessing the contents of memory is performance on recall and recognition tasks. It is difficult to isolate the various short-term memory processes since memory, as measured by performance, is influenced by encoding and retrieval factors. MSTM has, in addition to cognitive encoding and retrieval factors, unconscious encoding and retrieval factors, particular to motor memory, that may alter reproduction or recognition of a to-be-remembered item. Unconscious components refer to those aspects of a movement that remain unperceived by a subject but have modifying effects on movement reproduction. Such components include movement

speed, movement extent and movement range (Hall, 1977).

MSTM research on unconscious components was first conducted by Woodworth (1899). He was the first MSTM researcher to report the phenomenon of small movements being regularly exaggerated, while large movements are regularly made too small in comparison to the criterion movement. This overshooting tendency for short movements and undershooting tendency for long movements has been termed the range effect (Pepper & Herman, 1970).

This effect, in which small stimulus intensities are overestimated and large stimulus intensities are underestimated, when an individual is presented with a series of stimuli along the same dimension, has been reported repeatedly since the early beginning of psychophysical research. Hollingworth (1909, 1910) referred to this judgmental shift as the central tendency effect. He proposed that each judgment is shifted toward the mean magnitude of the range being considered. The central tendency is considered to be a conceptual process which interferes with the process of comparison and recognition.

The central tendency or range effect has been given extensive consideration in the MSTM literature (Hall, 1977, Stelmach, 1974; Wilberg & Girouard, 1975) and has been found in virtually all of the recent studies of motor memory in which a series of movement lengths or positions is included as a variable (Duffy, Montague, Laabs, and Hillix, 1975; Hagman, 1978; Hall & Wilberg, 1977, 1978;

Keele & Ells, 1972; Kelso, 1977; Kerr, 1978; Laabs, 1973, 1977; Marteniuk, 1973; Stelmach, 1970; Stelmach & Wilson, 1970; Wallace, 1977).

Assimilation Effects

The central tendency effect has been incorporated into the more general theory of adaptation-level (Helson, 1947, 1948, 1959, 1964). The central tendency effect is proposed to be a special case of adaptation-level theory occurring only when the method of single judgment is employed or when the standard is within the stimulus range (Hall, 1977; Helson, 1964).

It is evident from Helson's adaptation-level theory that it involves assimilation as defined by Lauenstein (1932). The subtle difference between the two theories, Lauenstein (1932) and Helson (1947), is that adaptation-level takes into account assimilation not only with the stimuli presented within a trial, but assimilation of all stimuli presented during the experiment, together with memorial representation of past similar stimuli on the same dimension (residuals). Assimilation (Lauenstein, 1932) refers to a shift in CE as a result of stimulation given either prior to, interpolated between, or following the standard and comparison judment. The CE changes are generally in the direction of the level of stimulation.

The assimilation effect represents one of the most prevalent findings in perceptual judgment studies.

Guilford and Park (1931) were the first researchers to employ the method of constant stimuli with interpolated anchors. Using lifted weight as stimuli, their results indicated a shift in CE toward the interpolated anchor, and hence they suggested an assimilation process to be the cause. The anchor is believed to pool (assimilate) with the standard and form a new level against which the comparison stimulus is compared. The relative size of the anchor stimulus determines the negative or positive shift in CE and hence the shift in judgmental decision.

Philip (1947) was one of the first researchers to test experimental conditions where the interfering anchor stimulus in addition to appearing between the two stimuli for comparison (interpolated condition), was presented before (preceding) the standard, and also after (following) the comparison stimulus. Philip's interpretation of his results suffer from the need to postulate three theories to account for them. The theories involve factors of set, fading of traces (disintegration), and assimilation. No one factor can account for the findings of the research, but Philip suggests some combination of all three factors might be construed as a possible explanation.

In Philip's study subjects compared temporal intervals, 1.01 seconds in length. The findings for the three conditions of anchor placement are interpretable from an adaptation-level point of view. When the anchor precedes, it is assumed to pool with the standard to form a new

adaptation-level against which the comparison is judged. This new adaptation-level will be moved in the direction of the anchor magnitude. Similar results will occur for the interpolated condition, with anchor and standard pooling to form a new adaptation-level. When the anchor follows the comparison stimulus if it is assumed the anchor pools with the comparison to form a new adaptation-level against which the standard is judged, this would account for the results of Philip. This latter condition however, is not clear as the standard and comparison should have pooled before the presentation of the anchor. The adaptation-level theory for this condition is far from clear.

Assimilation effects have been frequently reported in movement reproduction studies. Positive and negative shifts in CE have been reported when anchoring stimuli have been introduced. However, variation in presentation of the anchor (i.e. preceding, interpolated, and following) has not been well studied in MSTM research.

Preceding Anchors

There are only a few MSTM research studies that have included preceding anchor stimulation. Craft and Hindrichs (1971) conducted a series of experiments involving the presentation of a standard and an interfering movement, followed by a reproduction. A significant shift in CE (assimilation) was found when the interfering movement preceded the standard. In a similar experiment, Craft (1973)

found the assimilation effect over an immediate and 20 second delay, but not when a 20 second interval was introduced between anchor and standard. Increasing the delay between anchor and standard would seem to affect the process of assimilation. The results of Needham (1935b) previously reported, support this view. Needham suggested that as the time interval lengthens, the anchor becomes more and more remote (temporally and phenomenally) from the standard, and so its effectiveness as a 'disturbing factor' decreases.

Herman and Bailey (1970) found no shift in CE when studying force reproductions that were preceded by smaller or larger forces. Two possible reasons which may have contributed to the lack of assimilation are: (i) the standard was presented with concurrent visual feedback via an oscilloscope, and (ii) the direction of application of the preceding anchor force was opposite to that of the standard.

The direction of the anchor may well have been the contributing factor in the Herman and Bailey study. Stelmach and Barber (1970) reported similar findings of no directional biasing when the anchor was presented in the opposite direction to the standard. It may be that the subject views the reversed anchor as a potential member of another series entirely. If this were the case, assimilation between anchor and standard would be severely restricted (Helson, 1964).

<u>Interpolated Anchors</u>

A large number of motor memory studies report assimilation due to interpolated anchor movements (Craft, 1973; Craft & Hindrichs, 1971; Herman & Bailey, 1970; Laabs, 1974; Patrick, 1971; Pepper & Herman, 1970; Stelmach & Kelso, 1975; Stelmach & Walsh, 1972, 1973; Trumbo, Milone, and Noble, 1972).

The general findings can be summarized as follows:

(i) Reinforcement (number of repetitions) of the interpolated anchor significantly increases the shift in CE. (Patrick, 1971)

(ii) Introduction of the interpolated anchor at the end of the retention interval is more detrimental to recall than when the interpolated anchor is presented at the beginning of the retention interval (recency effect), (Patrick, 1971; Stelmach & Walsh, 1973).

(iii) Recency effects of the interpolated anchor elicit greater shifts in CE than do the number of reinforcements of the interpolated anchor (Patrick, 1971).

(iv) The degree of shift in CE is not directly related to the level of difficulty of the interpolated anchor measured in terms of information reduction (Williams, Beaver, Spence and Rundel, 1969; Tannis, 1972; Kantowitz, 1974).

(v) The degree of shift in CE is not directly related to the number of different interpolated anchors (Roy, 1972).

(vi) The length of an interpolated anchor causes an assimilation effect for distance reproduction and the end locations of an interpolated anchor cause an assimilation effect for location (Laabs, 1974).

Following Anchors

Due to the nature of the experimental paradigms employed in MSTM research, no study has considered the effect of an anchor stimulus presented following the standard and comparison stimuli.

Interference Theory

One of the oldest and most widely held explanations of forgetting is that people forget an event because something else they have learned prevents the event from being remembered. The interference theory of forgetting really consists of two sub-theories. The first one deals with the fact that earlier learning interferes with our ability to recall newly learned material, a phenomenon called *proactive* interference. The other sub-theory deals with the fact that new learning interferes with our ability to recall previously learned material, a phenomenon called *retroactive* interference (Loftus & Loftus, 1976).

The introduction of an anchor stimulus before a standard stimulus sets up a condition of proactive interference which parallels the more established experimental technique used in classical verbal memory studies. Similarly, an interpolated anchor between standard and comparison, produces a comparable retroactive interference condition.

In a perceptual judgment study, Gleitman (1957) studied the effects of proactive and retroactive assimilation with successive comparison of loudness, in a manner similar to that described above. This study was based on the ideas of Melton and Von Lackum (1941) who suggested that when time intervals between original learning and test are relatively short, proactive interference is weaker than retroactive interference. Gleitman, using only anchors larger than standard and comparison found both a proactive and retroactive assimilation effect. The large anchor produced a positive time-error in both conditions. Nonsignificance was found however, between the retroactive and proactive interference effects. The retroactive interference effect was no stronger than proactive interference, if anything the opposite trend was in evidence.

The results of Gleitman are in contrast to the earlier findings of Philip (1947) whose results suggest that retroactive interference is more potent than proactive interference. However, neither study produced significant effects, only differences in trends.

In the area of MSTM two studies (Craft & Hindrichs, 1971; Craft, 1973) compared the relative effects of proactive and retroactive assimilation. In both studies it was demonstrated that retroactive interference effects are greater than proactive interference effects. Herman and Bailey (1970) employing force stimuli, found a similar trend and concluded that while retroactive interference effects in MSTM are readily apparent, proactive interference effects in MSTM are, at best, weak.

The MSTM studies above, have demonstrated that an interfering movement may act both proactively and retroactively in producing interference with recall of a standard movement, but retroactive interference is a more potent source of interference with a motor response than is proactive interference. In other words, the magnitude of interference produced by one motor response upon recall of another is dependent upon the sequential order of the two responses. This finding is also in empirical agreement with studies of verbal short-term memory, where it has been observed that proactive interference effects are of lesser magnitude than are retroactive interference effects (Postman, 1964; Wickelgren, 1966).

MSTM Theories

The study of short-term retention of simple motor responses indicates that movements executed either prior to or following the execution of a criterion response reduce

the recall accuracy of the criterion response. Such movements (anchors) tend to cause a shift in CE in the direction of their magnitude. MSTM researchers have evoked the principles of adaptation (Helson, 1964) and assimilation (Lauenstein, 1932) to account for this directional biasing.

Pepper and Herman (1970)were the first MSTM researchers to attribute directional biasing to assimilation effects. They observed directional biasing of a recalled motor response in an experiment which used only one level of interfering force above and one level below the magnitude of the criterion force. They attributed their findings to assimilation effects (Helson, 1964) in that the recalled response moves in the direction of the changed level of stimulation derived from proprioceptive stimulation occurring during an interpolated task. More specifically, Pepper and Herman assumed that (a) an accurate memory trace or representation of the intensity or extent of a motor response is initially stored, but is subject to decay over time; (b) the decay occurs on the dimension of represented intensity or extent of the response; (c) the trace produced by two responses interact to produce a trace of intermediate intensity or extent; and (d) during recall, the subject makes his response by attempting to reproduce the momentary represented intensity of the decaying memory trace. Pepper and Herman (1970) have advanced a dual process theory that relies on both decay and interference to explain directional

biasing.

Stelmach and Walsh (1972, 1973) put forward a relative trace strength theory. The temporal placement of an anchor stimulus is seen as the important factor in determining the degree or magnitude of directional biasing. An assimilation process similar to that put forward by Pepper and Herman (1970) is postulated, but the determining factor is the temporal placement of anchor and standard. The criterion trace is believed to decay and hence become weakened and more susceptible to interference as time increases. The weaker the criterion trace at the time of the interpolated act, the greater the interference effect. Thus, for a given retention interval, the temporal spacing between the criterion and the interpolated anchor is seen as one of the determiners of directional biasing.

Stelmach and Walsh (1972, 1973) studied the reproduction accuracy of radial arm movements when large and small anchor stimuli were presented at various time intervals following the criterion. Increasing the retention interval between standard and anchor produced a nonsignificant but systematic shift in CE, which Stelmach and Walsh interpreted as support for their relative trace strength theory.

Criticisms of the relative trace strength theory are in the form of results obtained in other MSTM studies. Presenting an anchor before a standard results in the usual assimilation effects (Craft & Hindrichs, 1971). Increasing the retention interval between anchor and standard in this

condition, should, according to relative trace strength theory, weaken the anchor stimulus trace. This weakened trace is presumed to be more susceptible to interference and pooling with the standard and hence an increase in the shift of CE is predicted. Craft (1973) found just the opposite to be the case. Limiting the time interval between anchor and standard produced greater directional biasing than when the retention time was increased. Further, the relative trace strength model has difficulty in accounting for results obtained with small anchor stimuli. Many MSTM researchers (Patrick, 1971; Stelmach & Walsh, 1972, 1973) have failed to find directional biasing with anchor stimuli smaller than the criterion. No reasons are postulated by MSTM researchers to account for the effects of small anchors.

The situation in which a standard stimulus is followed by a weaker extraneous stimulus raises difficult questions of interpretation. Pratt (1933) reports that this condition leads to a greater negative time-error than one in which no anchor is presented. She uses this argument against the exclusive determination of time-error by assimilation processes. Gleitman and Hay (1964) state that one is not sure of what actually happens nor of what should happen on theoretical grounds when small anchors are used. The problem of interpretation of what should happen with small anchors on theoretical grounds is tied to the problem of the anchor trace. It could be assumed that anchors smaller than the

standard are 'weaker' and hence offer little interference for pooling. On the other hand a weakened trace has been suggested ideal for interference and pooling (Stelmach & Walsh, 1972, 1973). It is obvious this position is far from clear and further research is required utilizing anchors of varying degrees less than the standard stimulus.

Laabs (1973) put forward a model based on Helson's (1964) adaptation-level theory to account for directional biasing due to anchors. Laabs suggests assimilation effects take place but the underlying processes that are assumed to be involved are completely different from those envisioned by Pepper and Herman (1970). Pepper and Herman suggest a reproduction is made in reference to a single augmented memory trace. In Laabs' model a reproduction is made in reference to an average or central movement in addition to the memory trace of the criterion. In summary, the main assumption of the Laabs model is that subjects reproduce a movement both in reference to the memory trace of the movement and in reference to the adaptation-level of the set of movements presented. This model is directly in line with Helson's adaptation-level theory which insists on the inclusion of residual and contextual stimuli in addition to the actual to-be-remembered item (focal stimulus).

Overview of MSTM Theories

The three theories reviewed (Pepper & Herman, 1970; Stelmach & Walsh, 1972, 1973; Laabs, 1973) are all based on assimilation theory. Pepper and Herman (1970) postulate an assimilation effect in line with the original concept of Lauenstein (1932). Stelmach and Walsh (1972, 1973) put forward a relative trace strength hypothesis which is based on assimilation processes (Lauenstein, 1932). The Laabs (1973) model is a reformulation of Helson's (1964) adaptation-level theory to account for movement information retention. This model is the most comprehensive of the three theories, postulating assimilation processes which take into account background and residual stimuli. The quantification of Laabs' model however, is missing and represents the next step in its validation.

Summary

When anchor stimuli are involved in comparative perceptual judgment studies assimilation processes have been postulated to account for response biasing (Helson, 1947, 1948, 1959, 1964; Lauenstein, 1932). Similar assimilation processes have been postulated to account for directional biasing in the reproduction of a criterion movement when anchor movements have been presented either before or after the criterion (Craft, 1973; Herman & Bailey, 1970; Laabs, 1973; Pepper & Herman, 1970; Stelmach & Walsh, 1972, 1973). Such assimilation processes, while

explaining the majority of results in MSTM directional biasing studies, fail to account for the results of a number of anchoring conditions tested (Laabs, 1971; Levin, Norman, and Dolezal, 1973; Stelmach & Walsh, 1972, 1973; Patrick, 1971). If assimilation, as postulated by the various theories is operating, then why does the biasing phenomenon not exhibit itself in all conditions? There are two possible answers to this question: (i) the various methodologies and research paradigms employed in MSTM studies may not be sensitive enough to highlight the assimilation effect; and/or (ii) assimilation may not be the only process in effect, or indeed, assimilation may not be operating in the judgmental processing at all.

APPENDIX B

Recognition Paradigms and MSTM Studies

Over the past 10 years there has been a dramatic increase in the number of studies investigating the retention of a discrete movement response. This interest is in great part due the suggestion of Adams & Dijikstra (1966) that verbal and motor responses in motor short-term memory reflect the operation of different mechanisms. Virtually all of this research has employed a production measure of recall. Typically, a subject is presented a criterion movement distance which he must later duplicate (method of adjustment). Although the method of adjustment is a simple and obvious procedure for making matching settings, it has sometimes been criticized on several grounds.

First, it can be argued that since the method of adjustment requires the subject to physically manipulate some object, we are inadvertently studying not only perceptual characteristics of the subject, but also his motor skills. For instance, a distance reproduction eliciting a CE of -2 cm shows a slight tendency for the subject to underestimate the criterion distance *or* to overestimate the length of his reproduction. It can be argued that a subject really does have an accurate internal representation of the distance but, due to difficulties in the production of a motor response, cannot accurately generate the required movement.

A second difficulty concerns the actual movements made

by the subject. To eliminate usual cues, the subject is presented the criterion movement under a blind condition. Presentation of the criterion movement involves the subject moving a slide for instance, at constant velocity until arrested by a physical stop. The reproduction of this movement length however, involves a deceleration phase, since the lack of a physical stop prevents an instantaneous loss of velocity. The subject is required to perform two different tasks on presentation and reproduction, and therefore what is being tested for retention is unclear (Bahrick, Fitts, and Schneider, 1955). The observed decrement (error) may not be due to, say, assimilation, but instead to a difference between task requirements on presentation and recall trials.

These difficulties can be minimized by substituting a recognition test of memory for the method of adjustment test used in reproduction accuracy tasks.

Very few MSTM studies have included a recognition paradigm. Problems faced by researchers who did use recognition tests involved the degree of adjustment between the items presented for recognition. An early attempt to scale this adjustment in recognition MSTM involved the method of constant stimuli (Leuba, 1909). Kantowitz (1969) had little success with the method of limits.*

* A full description of these classical psychophysical methods is offered by Woodworth & Schlosberg (1954).

However, Kantowitz (1974) had more success with a method for scaling task difficulty based on Fitts' (1954) Index of Difficulty (ID). Comprehensive descriptions of the methods just outlined will not be presented here as the MSTM recognition paradigm to be proposed and outlined later does not involve the problem of scaling task difficulty. However, the findings from the few MSTM recognition studies are worth briefly reviewing.

Marshall (1972) using a two-interval forced choice recognition paradigm found detrimental effects of retention interval (unfilled) on distance recognition performance. However, Kantowitz (1974) failed to find any decrement in distance recognition performance over either a filled (interpolated tapping task) or unfilled retention interval employing the more conventional same-different judgments. The different procedures employed in the two studies may possibly account for the conflicting findings. Both Kantowitz and Marshall found that kinesthetic information recognition accuracy increased with the amplitude of the movement, and, furthermore, performance varied with the type of recognition judgment (same or different) made by the subject. When the distance to be recognized was longer than the criterion distance subjects were better able to discriminate the difference than when the distance to be recognized was shorter than the criterion.

This finding, in both the Kantowitz and Marshall studies, that a stimulus shorter than the criterion causes

recognition discrimination problems can be interpreted from a context point of view, as the short movement can be considered an anchor stimulus. Anchors of magnitude less than the standard have, in many studies of context effects, been found to be ineffective in directional biasing (Patrick, 1971; Stelmach & Walsh, 1972, 1973). The Kantowitz (1974) and Marshall (1972) results further support the ineffectiveness of anchors smaller than standard. Anchors of magnitude value less than the standard stimulus appear to have difficulty in establishing an equal or superior presence in the judgmental process.

Both Kantowitz (1974) and Marshall (1972) presented anchors before and after the criterion, however, they only present data in collapsed form and so it is not possible to comment on proactive and retroactive interference effects.

Finally, Hall (1977) and Wilberg and Hall (1976) have successfully studied range effect with both recall and recognition paradigms. These studies, together with the results of research by Kantowitz (1974) and Marshall (1972) support the conclusion that movement distance can be accurately recognized.

Method of Constant Stimuli with Interpolated Anchors

In reviewing the various theories of context effects, it was recommended that the category scaling procedure is not advisable. The present series of investigations is concerned with context effects which are independent of

response language and, therefore, it was decided to adapt a technique which excludes response factors of the sort described by Stevens (1958).

One such procedure is the "method of constant stimuli with interpolated anchors." It is different from ratings in categories, or more natural metrics, in that numbers are not assigned to stimuli. Instead, judges decide which of two quantities or qualities is higher, heavier, sweeter, longer, etc. Nominally, such judgments are made on the basis of the sensations which each of the stimuli, to be compared, give rise to. The method is, consequently, free of the possibility of semantic adjustments.

The method of constant stimuli with interpolated anchors involves presenting a standard stimulus followed by a (usually) non-judged anchor stimulus, followed by a comparison stimulus. It was developed originally, to validate certain Gestalt principles (Guilford & Park, 1931), but quickly became a popular means of studying time-error. Some of the investigators who used it, and the modalities they chose to work with are listed below in Table B1.

In all cases it was found that an interpolated anchor, greater than standard and comparison, led to a positive time-error, whilst one less than standard and comparison, produced more negative time-error. In other words, large interpolated anchors cause the comparison stimuli to seem smaller, and small interpolated anchors lead to their seeming greater than when no stimulus is interpolated

between standard and comparison. Although the various authors confined discussion of these results strictly to time-error, clearly, it is possible to interpret their results in terms of context effects and to pronounce that a contrast or assimilation effect was operating.

Investigators	Judgments
Lauenstein (1932)	Auditory Intensity
Pratt (1933)	Auditory Intensity
Wada (1935)	Auditory Intensity
Needham (1935a)	Auditory Intensity
Cramwell (1941)	Vertical Distances
Marchetti (1942)	Line Lengths
Philip (1947)	Time Estimation
Holzman & Klein (1954)	Auditory Intensity, Brightness, Weights
Gumenik & Weiss (1967)	Weights
Ellis (1971, 1972, 1973a, 1973b)	Auditory Intensity, Spacial Size

TABLE B1 Some studies in which the method of constant stimuli was used to study time-error.

Some investigators have used the method of constant stimuli with interpolated anchors in order, specifically, to examine context effects. Dinnerstein (1965), and Dinnerstein, Curcio and Chinsky (1966), used weights; Parducci, Marshall, and Degner (1966) used squares; and in a series of experiments by Ellis (1971), triangles and auditory tones were employed. In all five investigations

the interpolated anchor was observed to induce response biasing.

KAK Paradigm

The method of constant stimuli with interpolated anchors was modified by Underwood (1966). He briefly outlines a previously unpublished experiment in which the standard and comparison stimuli were always equal. The stimuli were equilateral triangles, and anchor stimuli larger, smaller, and equal to standard and comparison were interpolated between them. Subjects were required to report whether the third stimulus (comparison) was larger or smaller than the first stimulus (standard), although objectively, they were equal.

This method had already been used by Philip (1947) in a time-error study, and Arons and Irwin (1932) had employed equal standard and comparison weights in a study of response repetition patterns. Underwood, however, originated the application to the study of context effects. He found that, following a large interpolated anchor the comparison stimulus was judged smaller than standard, and after a small interpolated anchor, it was more often judged larger.

The Underwood method has been labelled the KAK paradigm (Ellis, 1971), which represents two constant stimuli (K) and one interpolated anchor (A).

APPENDIX C

Table C1

Analysis of Variance

Experiment 1: Judgments of K2<K1

SOURCE	df	MS	F
ORDER (O)	1	0.004	0.17
ANCHOR SIZE (AS)	2	0.003	0.05
O X AS	2	0.028	1.22
ANCHOR PLACEMENT (AP)	2	0.033	0.38
O X AP	2	0.003	0.21
AS X AP	4	0.061	1.56
O X AS X AP	4	0.015	0.34
SUBJECTS (S)	7	0.455	
O X S	7	0.023	
AS X S	14	0.062	
O X AS X S	14	0.023	
AP X S	14	0.087	
O X AP X S	14	0.014	
AS X AP X S	28	0.039	
O X AS X AP X S	28	0.044	

Table C2

Analysis of Variance

Experiment 1: Trials Without an Anchor Stimulus

SOURCE	df	MS	F
ORDER (O)	1	26.28	5.18
INTERSTIMULUS INTERVAL (I)	1	0.78	0.42
O X I	1	3.79	2.43
SUBJECTS (S)	7	0.92	
O X S	7	5.07	
I X S	7	1.85	
O X I X S	7	1.56	

Table C3

Analysis of Variance

Experiment 2: Judgments of K2<K1

SOURCE	df	MS	F
LOCATION CONDITIONS (1)	2	0.286	3.28
ORDER (O)	1	0.223	1.90
L X O	2	0.030	3.60
ANCHOR SIZE (AS)	2	0.167	6.92*
L X AS	4	0.052	1.11
O X AS	2	0.003	0.07
L X O X AS	4	0.030	0.85
ANCHOR PLACEMENT (AP)	2	0.036	0.54
L X AP	4	0.063	1.08
O X AP	2	0.095	3.87
L X O X AP	4	0.040	0.83
AS X AP	4	0.095	1.94
L X AS X AP	8	0.109	2.42
O X AS X AP	4	0.138	3.21
L X O X AS X AP	8	0.043	1.00
SUBJECTS (S)	8	0.715	
L X S	16	0.087	
O X S	8	0.117	
L X O X S	16	0.083	
AS X S	16	0.024	
L X AS X S	32	0.046	
O X AS X S	16	0.042	
L X O X AS X S	32	0.035	
AP X S	16	0.067	
L X AP X S	32	0.058	
O X AP X S	16	0.025	
L X O X AP X S	32	0.048	
AS X AP X S	32	0.049	
L X AS X AP X S	64	0.045	
O X AS X AP X S	32	0.043	
L X O X AS X AP X S	64	0.042	

*$p < .05$

Table C4

Analysis of Variance

Experiment 3: Recognition versus Recall

SOURCE	df	MS	F
Ro vs. Ra (R)	1	16.67	2.04
ORDER (O)	1	1.17	0.27
R X O	1	8.51	4.28
ANCHOR SIZE (AS)	3	10.40	4.72*
R X AS	3	3.36	0.78
O X AS	3	3.75	1.33
R X O X AS	3	0.97	0.44
SUBJECTS (S)	8	10.50	
R X S	8	8.16	
O X S	8	4.44	
R X O X S	8	1.99	
AS X S	24	2.20	
R X AS X S	24	4.32	
O X AS X S	24	2.83	
R X O X AS X S	24	2.18	

*$p < .065$

Table C5

Analysis of Variance

Experiment 3: Constant Error

SOURCE	df	MS	F
ORDER (O)	1	0.04	0.01
ANCHOR SIZE (AS)	3	0.97	1.41
O X AS	3	0.28	0.82
SUBJECTS (S)	8	5.05	
O X S	8	2.91	
AS X S	24	0.69	
O X AS X S	24	0.34	

Table C6

Analysis of Variance

Experiment 3: Variable Error

SOURCE	df	MS	F
ORDER (O)	1	0.13	1.08
ANCHOR SIZE (AS)	3	0.03	0.02
O X AS	3	0.09	0.41
SUBJECTS (S)	8	0.34	
O X S	8	0.12	
AS X S	24	0.15	
O X AS X S	24	0.22	

Table C7

Analysis of Variance

Experiment 4: Recall Anchor Constant Error

SOURCE	df	MS	F
ORDER (O)	1	0.042	0.06
ANCHOR SIZE (AS)	4	7.63	8.48*
O X AS	4	0.40	0.68
SUBJECTS (S)	8	1.11	
O X S	8	0.73	
AS X S	32	0.90	
O X AS X S	32	0.59	

*$p < .025$

Table C8

Analysis of Variance

Experiment 4: Recall Anchor Variable Error

SOURCE	df	MS	F
ORDER (O)	1	1.33	2.08
ANCHOR SIZE (AS)	4	14.23	10.70*
AS X O	4	2.41	2.71
SUBJECTS (S)	8	3.39	
O X S	8	0.64	
AS X S	32	1.33	
O X AS X S	32	0.89	

*$p < .025$

Table C9

Analysis of Variance

Experiment 4: Recall Standard Constant Error

SOURCE	df	MS	F
ORDER (O)	1	0.07	0.07
ANCHOR SIZE (AS)	4	2.20	2.90
O X AS	4	0.46	1.10
SUBJECTS (S)	8	1.09	
O X S	8	0.97	
AS X S	32	0.76	
O X AS X S	32	0.42	

Table C10

Analysis of Variance

Experiment 4: Recall Standard Variable Error

SOURCE	df	MS	F
ORDER (O)	1	4.12	4.08
ANCHOR SIZE (AS)	4	7.50	4.63
O X AS	4	0.55	0.32
SUBJECTS (S)	8	7.92	
O X S	8	1.01	
AS X S	32	1.62	
O X AS X S	32	1.71	

Table C11

Analysis of Variance

Experiment 5: Recall Standard Constant Error

SOURCE	df	MS	F
BETWEEN GROUPS	3	124.79	13.04*
WITHIN GROUPS	76	9.67	
TOTAL	79		

*$p < .001$

Table C12

Analysis of Variance

Experiment 6: Recall Standard Constant Error

SOURCE	df	MS	F
STANDARD SIZE (SS)	1	329.22	75.65**
ANCHOR SIZE (AS)	4	36.27	7.65*
SS X AS	4	12.20	2.85
ORDER (O)	1	1.88	0.45
SS X O	1	0.98	0.20
AS X O	4	1.94	0.42
SS X AS X O	4	2.18	0.69
SUBJECTS (S)	9	16.38	
SS X S	9	4.35	
AS X S	36	4.74	
SS X AS X S	36	4.28	
O X S	9	4.20	
SS X O X S	9	5.02	
AS X O X S	36	4.63	
SS X AS X O X S	36	3.16	

** $p < .001$

* $p < .025$

Table C13

Analysis of Variance

Experiment 6: Recall Anchor Constant Error

SOURCE	df	MS	F
ORDER (O)	1	0.31	0.07
STANDARD SIZE (SS)	1	0.36	0.06
O X SS	1	15.29	12.23*
ANCHOR SIZE (AS)	4	16.96	1.71
O X AS	4	8.61	1.82
SS X AS	4	43.87	11.44*
O X SS X AS	4	0.66	0.13
SUBJECTS (S)	9	25.56	
O X S	9	4.51	
SS X S	9	5.77	
O X SS X S	9	1.25	
AS X S	36	9.72	
O X AS X S	36	4.74	
SS X AS X S	36	3.84	
O X SS X AS X S	36	4.98	

*$p < .01$

Table C14

Analysis of Variance

Experiment 7: Judgments of K2<K1

SOURCE	*df*	*MS*	*F*
ANCHOR POSITION (AP)	2	0.07	1.40
ANCHOR SIZE (AS)	2	0.17	4.25*
AP X AS	4	0.29	4.83*
SUBJECTS (S)	9	0.17	
AP X S	18	0.05	
AS X S	18	0.04	
AP X AS X S	36	0.06	

*$p < .05$